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Debris/Ice/TPS Assessment And Integrated Photographic Analysis For Shuttle Mission STS-49

July 1992

National Aeronautics and
Space Administration

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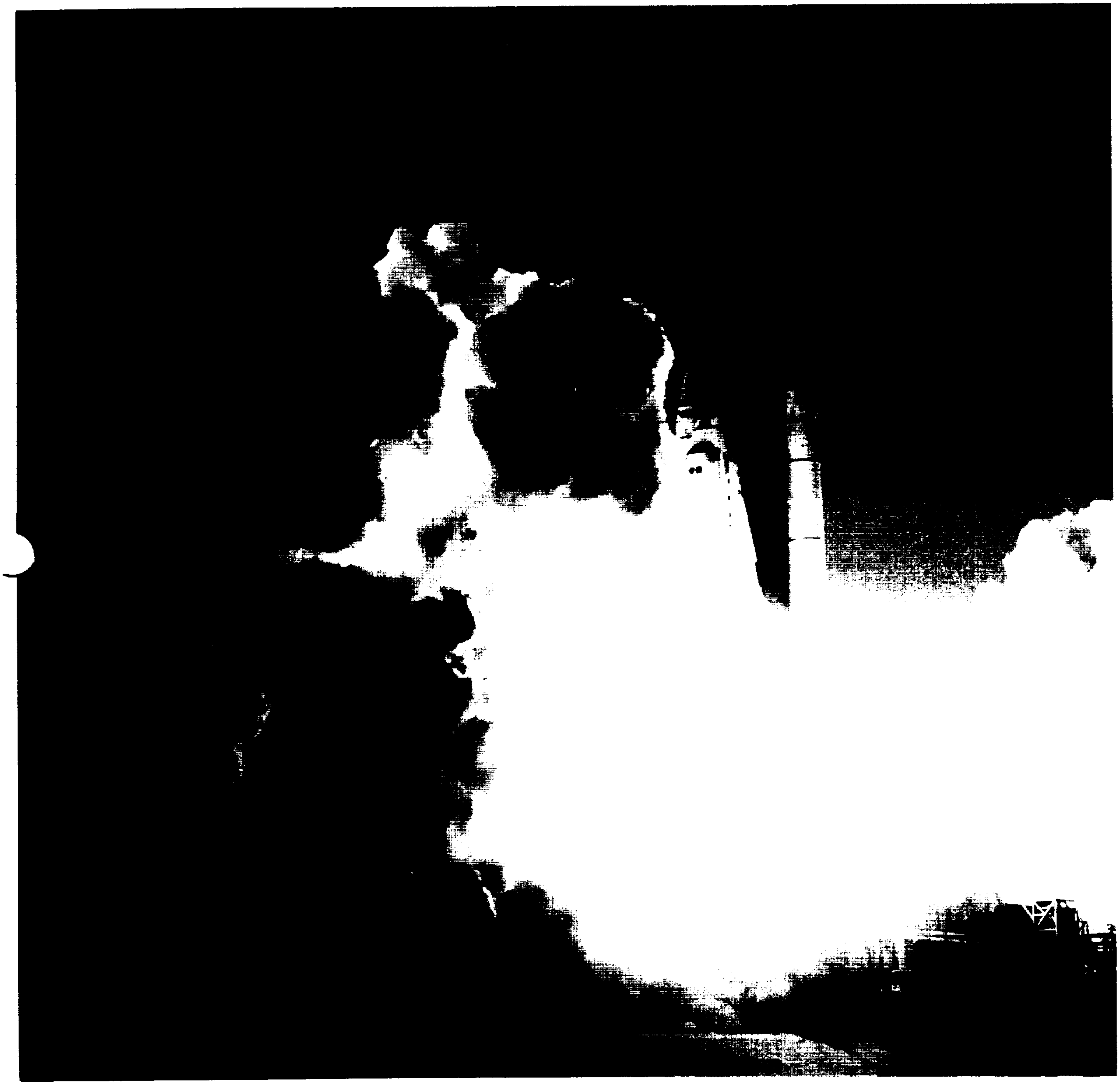
FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center (KSC) Photo/Video Analysis, reports from Johnson Space Center, Marshall Space Flight Center, and Rockwell International - Downey are also included to provide an integrated assessment of each Shuttle mission.



Shuttle Mission STS-49 was launched at 7:40 p.m. local 5/7/92

1.0 Summary

In addition to the Debris/Ice/TPS assessment, this report provides an integrated Photographic Analysis of Shuttle Mission STS-49 with contributions from KSC, JSC, MSFC, and Rockwell - Downey.

The Flight Readiness Firing was conducted on 6 April 1992. From a debris standpoint, there were no major issues. During the Pre-Firing Inspection, a piece of rope was observed adhering to the LH2 tank TPS below the GUCP and approximately 85 feet above the MLP deck. Since the rope was not a debris concern and does not affect TPS performance, it will not be removed before launch. The presence of the rope was accepted by MRB.

The Ice Inspection revealed no Launch Commit Criteria, OMRS, or NSTS-08303 violations. A crack occurred in the intertank foam (-Y-Z quadrant) in the first stringer valley between the -Y thrust panel and the GUCP beginning at the LH2 tank-to-intertank flange and propagating forward. The crack was approximately 18-20 inches in length, 1/4-inch wide with no offset, and was not filled with ice or frost. IPR 49V-0314 was upgraded to a PR and dispositioned to use-as-is based on experience with similar TPS cracks at this location. A suspect crack 6 inches long was present in the -Y vertical strut cable tray forward facing surface at the tank acreage interface. A 4-inch diameter ice/frost formation with venting (blowing) purge gas was present on the LH2 umbilical 17-inch flapper valve actuator access port foam plug forward (top) corner. The ice and frost formations were acceptable for the test per NSTS-08303. MPS evaluated the venting/blowing purge gas and accepted the condition for the firing.

The Post FRF Drain Inspection revealed the intertank TPS crack had closed during tank warm-up and was not visible. Disposition of the IPR accepted the current condition for launch since it is typical of structural flexure cracks previously observed and the area is outside the debris zone. A hands-on inspection of the LO2 feedline support brackets revealed crushed/damaged BX-250, approximately 3.5"x1", on the outboard side of the XT-1129 attach point at the feedline surface. The damaged area was repaired with PDL foam. Some minor SLA damage occurred on the boomerang bracket. The Ice Team had reported the presence of a suspect 6-inch long crack on the forward face of the -Y vertical strut cable tray. The crack had closed during tank warm-up, but was still visible during the Drain Inspection. A stress relief cut in the TPS to allow for structural movement had been deleted by design on this tank at the factory. Since the surface is not cryogenic and sufficient foam remains for ascent aerothermal loads, the crack was accepted for launch. Tile surface coating material was missing

from a 10"x3" area on the body flap stub between SSME #2 and #3 near the body flap hinge. Loss of this material was most likely caused by SSME ignition vibration and acoustics.

The FRF Film/Video Analysis revealed a fore-and-aft movement (diaphram-like flexing) of the Orbiter base heat shield in the centerline area between the SSME cluster during engine start-up. The movement subsided as the SSME plume stabilized and the Mach diamonds formed. Measurements of this motion on the film analyzer showed the amplitude was 1.1 inches. Review of SSME ignition films revealed a similar motion in the same time frame on the other Orbiters. Structures engineering performed an assessment of the condition and found no anomaly.

The Pre-Launch Inspection of the pad and Shuttle vehicle was conducted on 6 May 1992. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (1st flight), ET-43 (LWT 36), and BI050 SRB's. There were no vehicle anomalies. Facility discrepancies were worked real-time or were entered into OMI S0007, Appendix K, for resolution prior to vehicle tanking.

The vehicle was cryoloaded for flight on 7 May 1992. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice/frost conditions outside of the established data base. The previous TPS anomalies (crack in the intertank TPS, a piece of rope on the LH2 tank, and a 6-inch TPS crack on the -Y vertical strut cable tray) had been accepted for launch. A 4-inch diameter ice/frost formation with venting (blowing) purge gas was present on the ET/ORB LH2 umbilical 17-inch flapper valve actuator access port foam plug forward (top) corner. This TPS plug had been replaced after the Flight Readiness Firing. The ice/frost formation was acceptable for launch per NSTS-08303. MPS evaluated the venting/blowing purge gas and deemed the condition acceptable for launch. Six Ice/Frost Team observation/anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. The LH2 umbilical leak sensors detected no significant hydrogen during the cryoload. The tygon tubing was successfully removed from the vehicle with no TPS contact or damage.

A debris inspection of Pad 39B was performed after launch. The only flight hardware found were two FRSI plugs, a common occurrence, from the Orbiter base heat shield. Launch damage to the holddown posts was minimal. EPON shim material on the south holddown posts was intact, but debonded. There was no visual indication of a stud hang-up on any of the south holddown posts. No frangible nut/ordnance fragments were found. Damage to the facility overall was minimal.

A total of 110 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. Film items E-76, 77, 19, 20 again showed a fore-and-aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster during engine start-up. The movement subsided as the SSME plume stabilized and the Mach diamonds formed. Measurements of the motion on the film analyzer showed the amplitude was 1.1 inches. No stud hang-ups occurred on the SRB holddown posts and no ordnance debris fell from the HDP DCS/stud holes.

Hand-held views of the External Tank after separation were not taken by the crew due to dark conditions. OV-105 was equipped to carry two umbilical cameras. No vehicle anomalies were visible during SRB separation. ET separation was not recorded by the umbilical cameras due to the dark conditions. Orbiter performance in the Heading Alignment Circle (HAC), final approach, landing gear deployment, flare, and touchdown appeared normal. First use of the drag chute, which was deployed just after nose wheel touchdown, was nominal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums exhibited a below average total of 14 debonds over fasteners. All Debris Containment System (DCS) plungers were seated properly with the exception of HDP #4, which was obstructed by frangible nut halves. This was the seventh flight utilizing the optimized link. None of the EPON shim material was lost during ascent. From a debris stand point, the recovered SRB's were in excellent condition.

A post landing debris inspection of OV-105 was conducted on May 16-17, 1992, at Ames-Dryden (EAFB) on runway 22 and in the Mate/Demate Device (MDD). The Orbiter TPS sustained a total of 114 hits, of which 11 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 55 hits, of which 6 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of Orbiter TPS debris hits was slightly less than average and the number of hits one inch or larger was much less than average.

The most significant tile damage measured 9-5/8 x 2-5/8 x 1/4 inches and was located on the right side of the vehicle just aft of the nosecap RCC. The size and depth of this damage site is indicative of an impact by a low density material such as External Tank TPS foam. The following items were found on the runway underneath the RH ET umbilical door: a piece of a Jo-bolt, a spacer (washer), and a Torx head screw. Another Torx head screw was found on the runway underneath the LH ET umbilical door. This flight marked the first use of the Orbiter drag chute. According to JSC Deceleration System engineering, the drag chute functioned nominally. However, two tiles, one on the lower (-Z) edge of the drag chute opening and the other on the LH lower edge of the vertical stabilizer "stinger", were damaged by the drag chute deployment. All drag chute hardware was recovered and showed no signs of abnormal operation.

A variety of residuals present in the post-landing Orbiter samples originated from sources such as Orbiter TPS, SRB BSM exhaust residue, natural landing site products, organics, and paint. The samples obtained from Orbiter vent door #9 after landing revealed no conclusive source of the discoloration on the outer surface. The source of a similar phenomenon on a previous mission (STS-42) also could not be determined. These data do not indicate a single source of damaging or discoloring debris as all of the other materials have been previously documented in post-landing samples reports.

One Post Launch Debris Anomaly and no IFA candidates were observed during this mission assessment.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition: NASA KSC, NASA MSFC, NASA JSC, LSOC SPC, RI - DOWNEY, MMMSS - MAF, USBI - BPC, MTI - UTAH

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective:	Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.
Areas:	MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle external surfaces
Time:	L - 1 day
Requirements:	OMRSD S00U00.030 - An engineering debris inspection team shall inspect the Shuttle and launch pad to identify and resolve potential debris sources. The prelaunch vehicle and pad configuration shall be documented and photographed.
Documents:	OMI S6444
Report:	Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective:	Evaluate ice/frost accumulation on the Shuttle and/or any observed debris utilizing OTV cameras.
Areas:	MLP deck, FSS, Shuttle external surfaces
Time:	T - 6 hours to Launch + 1 hour or propellant drain
Requirements:	OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.
Documents:	OMI S0007, OMI S6444
Report:	OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective:	Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.
Areas:	MLP deck, FSS, Shuttle external surfaces
Time:	T - 3 hours (during 2 hour BIH)
Requirements:	OMRSD S00U00.020 - An engineering debris inspection team shall inspect the Shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During the walkdown, inspect Orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles. An IR scan is required during the Shuttle inspection to verify ET surface temperatures. During the walkdown inspect ET TPS areas which cannot be observed by the OTV system.
Documents:	OMI S0007, OMI S6444
Report:	Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives:	Locate and identify debris that could have damaged the Shuttle during launch
Areas:	MLP zero level, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to the perimeter fence, walkdown of the beach from Playalinda to Complex 40, aerial overview of inaccessible areas.
Time:	Launch + 1 hours (after pad safing, before washdown)
Requirements:	OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware and resultant debris sources. The post launch pad and area configuration shall be documented and photographed.
Documents:	OMI S0007, OMI S6444

Report: Initial report to NTD and verbal briefing to Level II at L+8 hours; generate PR's.

5) Launch Data Review

Objective: Detailed review of high speed films video tapes, and photographs from pad cameras, range trackers, aircraft and vehicle onboard cameras to determine possible launch damage to the flight vehicle. Identify debris and debris sources.

Time: Launch + 1 day to Launch + 6 days

Requirements: OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the Shuttle. Identify flight flight vehicle or ground system damage that could affect orbiter flight operations or future SSV launches.

Documents: OMI S6444

Report: Daily reports to Level II Mission Management Team starting on L+1 day through landing; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective: Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.

Areas: SRB external surfaces (Hangar AF, CCAFS)

Time: Launch + 24 hours (after on-dock, before hydrolasing)

Requirements: OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Documents: OMI B8001

Report: Daily reports to Level II Mission Management Team. Preliminary report to SRB Disassembly Evaluation Team. Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective:	Identify and evaluate areas of Orbiter TPS damage due to debris and correlate if possible, source and time of occurrence. Additionally, runways are inspected for debris/sources of debris
Areas:	Orbiter TPS surfaces, runways
Time:	After vehicle safing on runway, before towing
Requirements:	OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.
Requirements:	OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photographic documentation of any debris, debris sources, or flight hardware that may have been lost on landing.
Requirements:	OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.
Requirements:	OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/ photographed and coordinated with the results of the post launch shuttle/ pad area debris inspection.
Requirements:	OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC nose cap and RCC RH wing leading edge panels 9 and 17.
Documents:	OMI S0026, OMI S0027, OMI S0028

Report: Briefing to NASA Convoy Commander and generate PR's. Preliminary report to Level II on the day of landing followed by a more detailed update the next day.

8) Level II report

Objective: Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 FLIGHT READINESS FIRING (FRF)

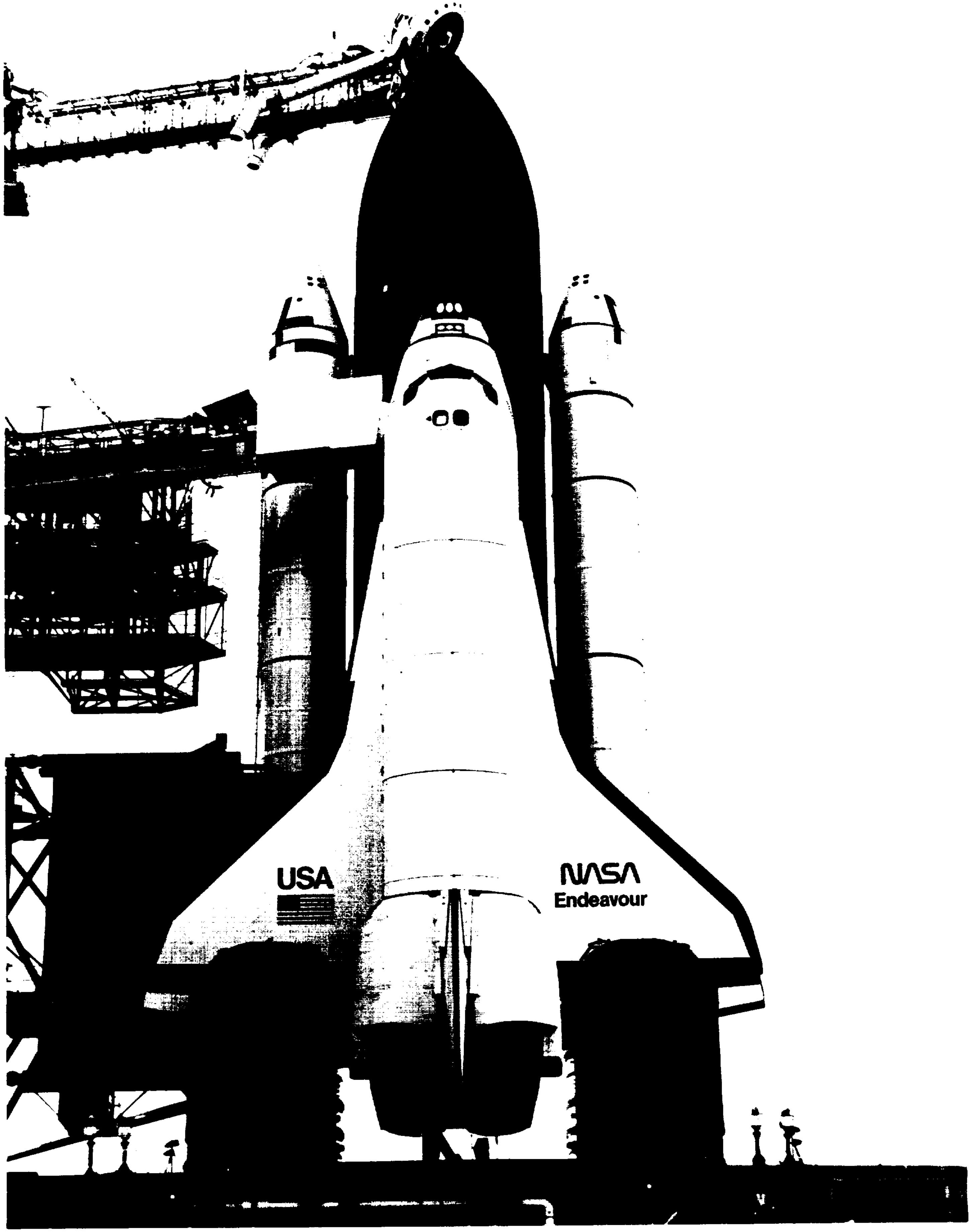
3.1 PRE-FIRING SSV/PAD DEBRIS INSPECTION

A pre-FRF debris inspection of the pad and Shuttle vehicle was conducted on 5 April 1992 from 0800 - 0930 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (FRF/1st flight), ET-43 (LWT 36), and BI-050 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/ launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended to remain in place during cryogenic loading and be removed by the Ice Team during the T-3 hour hold.

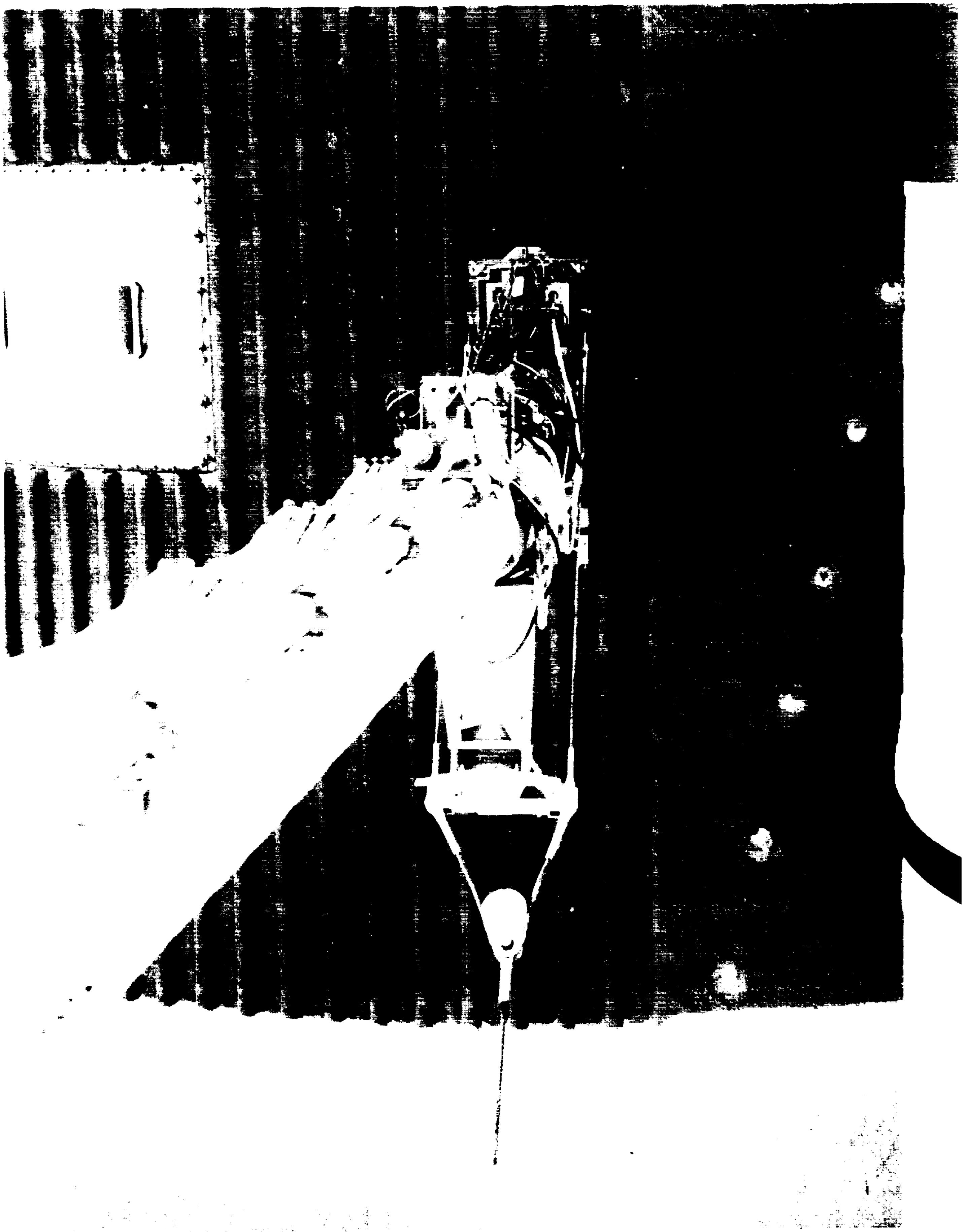
There were no significant vehicle anomalies. A piece of rope was observed adhering to the LH2 tank TPS below the GUCP and approximately 85 feet above the MLP deck. Since the rope was not a debris concern and does not affect TPS performance, it will not be removed before launch. The presence of the rope was accepted by MRB.

Several MLP deck access plate bolts had not been tightened. Loose debris, such as tie wraps, plastic bags, and retaining pins, lay on the MLP zero level. These discrepancies were corrected real-time by Pad Operations. Vacuuming, sweeping, and removing sand/small debris from the MLP deck, raised deck areas, and fence post holes was the only item entered in S0007, Appendix K.



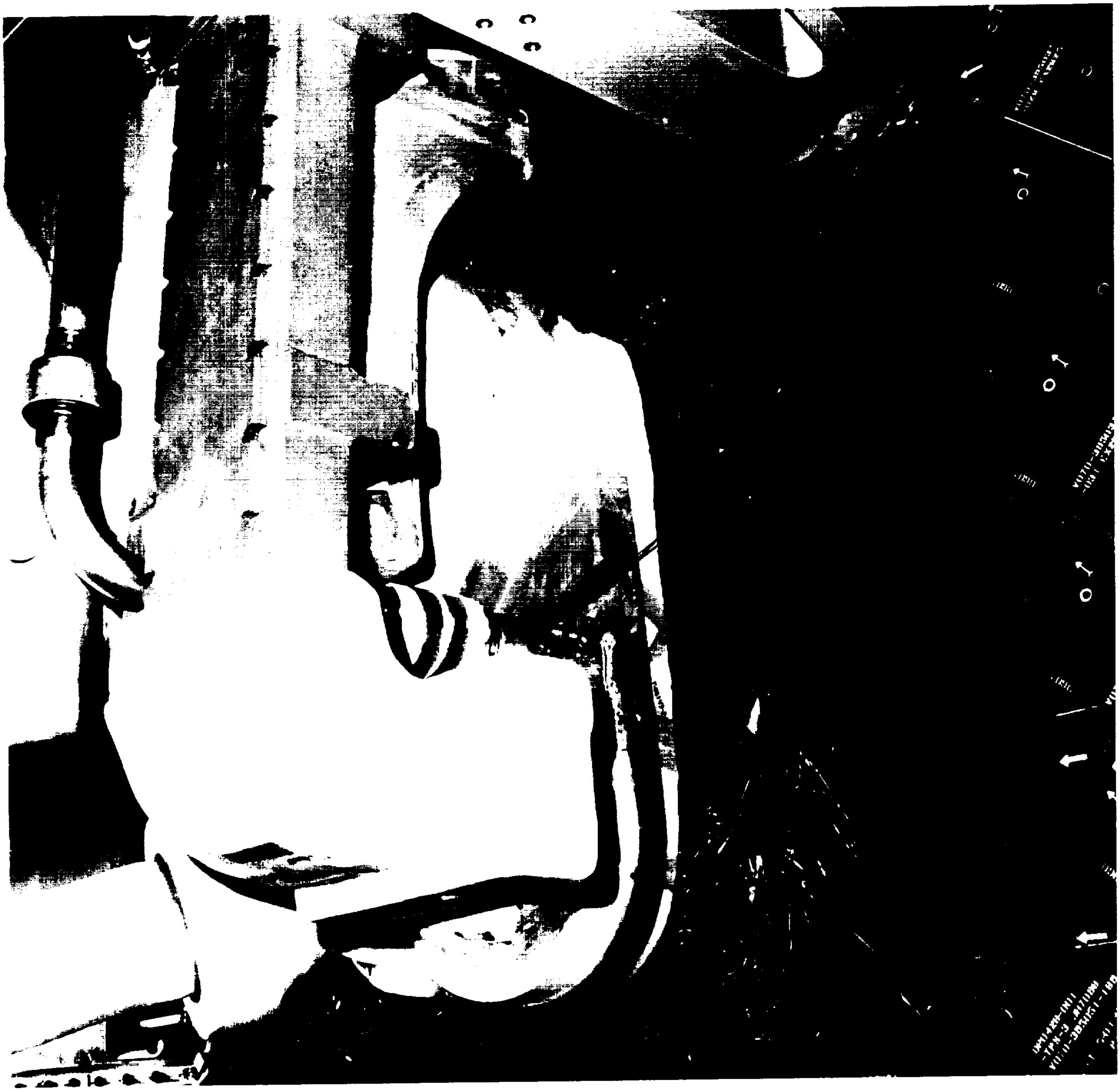
OV-105 Endeavour (1st flight), ET-43 (LWT 36), BI-050 SRBs

Overall view of RH wing lower surface tiles



Intertank thrust panel/stringer TPS prior to cryogenic loading

Configuration of the LH2 ET/ORB umbilical 17-inch flapper valve torque tool access port TPS plug prior to cryogenic loading



Overall view of LH2 ET/ORB umbilical. Instrumentation on LH2 pressurization line is for FRF only.

3.2 FRF ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 6 April 1992 from 0630 to 0800 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no conditions outside of the established data base.

The portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 1 and 2.

ORBITER

No Orbiter tile anomalies were observed. The water spray boiler plugs were intact. Light frost was present at the SSME #1 (2:00-9:00 o'clock) and #2 (full 360 degree circumference) heat shield-to-nozzle interfaces. The SSME #3 heat shield was dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No GOX vapors originated from inside the SSME nozzles. No condensate was present on base heat shield tiles.

SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 60 and 63 degrees F (Fahrenheit). All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 65 degrees F, which was within the required range of 44-86 degrees F.

EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

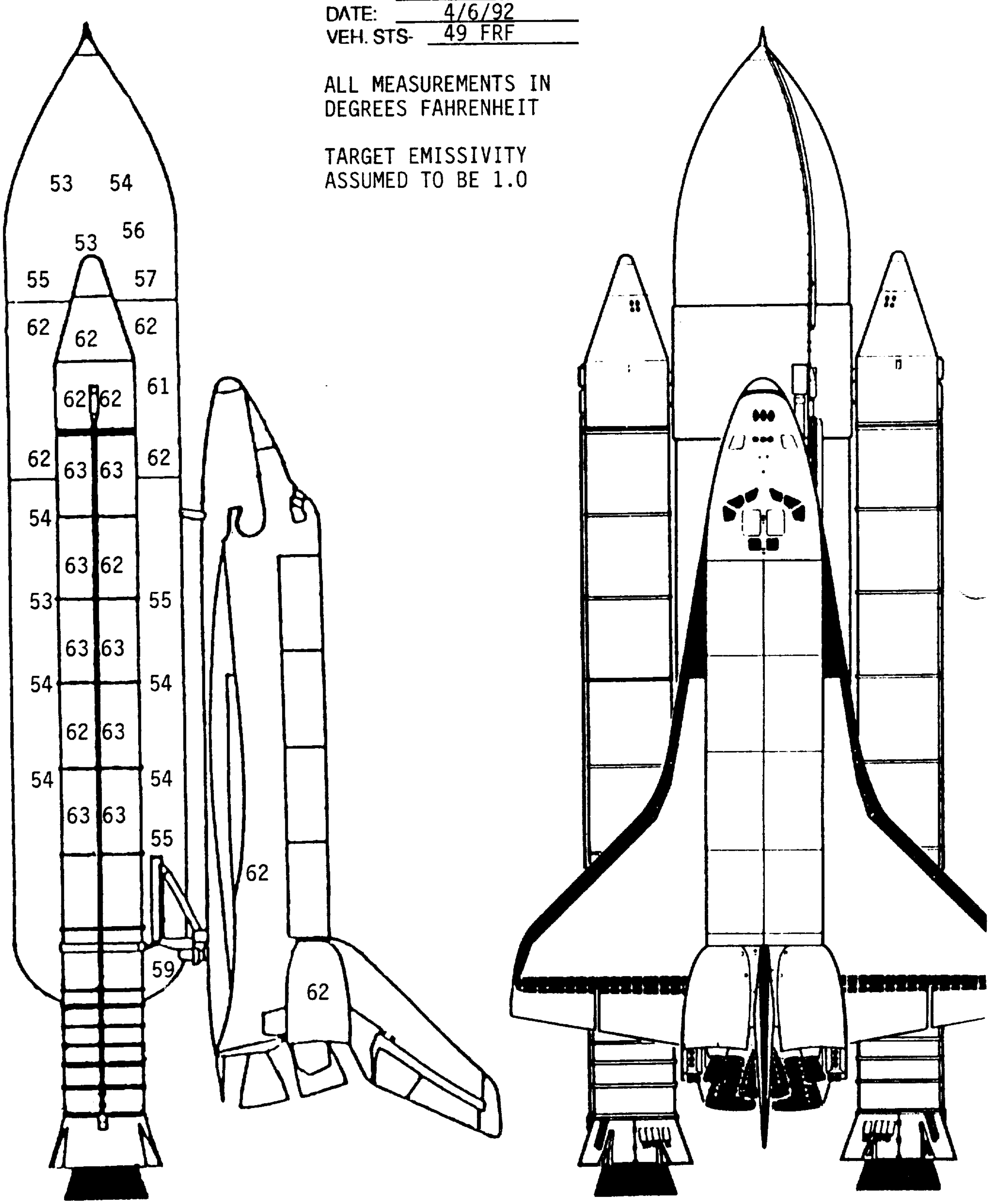
There was very light condensate but no ice/frost accumulation on the LO2 tank ogive and barrel sections. There were no TPS anomalies. The tumble valve cover was intact. The pressurization line and support ramps were in nominal configuration. The STI measured surface temperatures that ranged from 53 to 57 degrees F.

Figure 1. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0630 - 0800 EST
DATE: 4/6/92
VEH. STS- 49 FRF

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



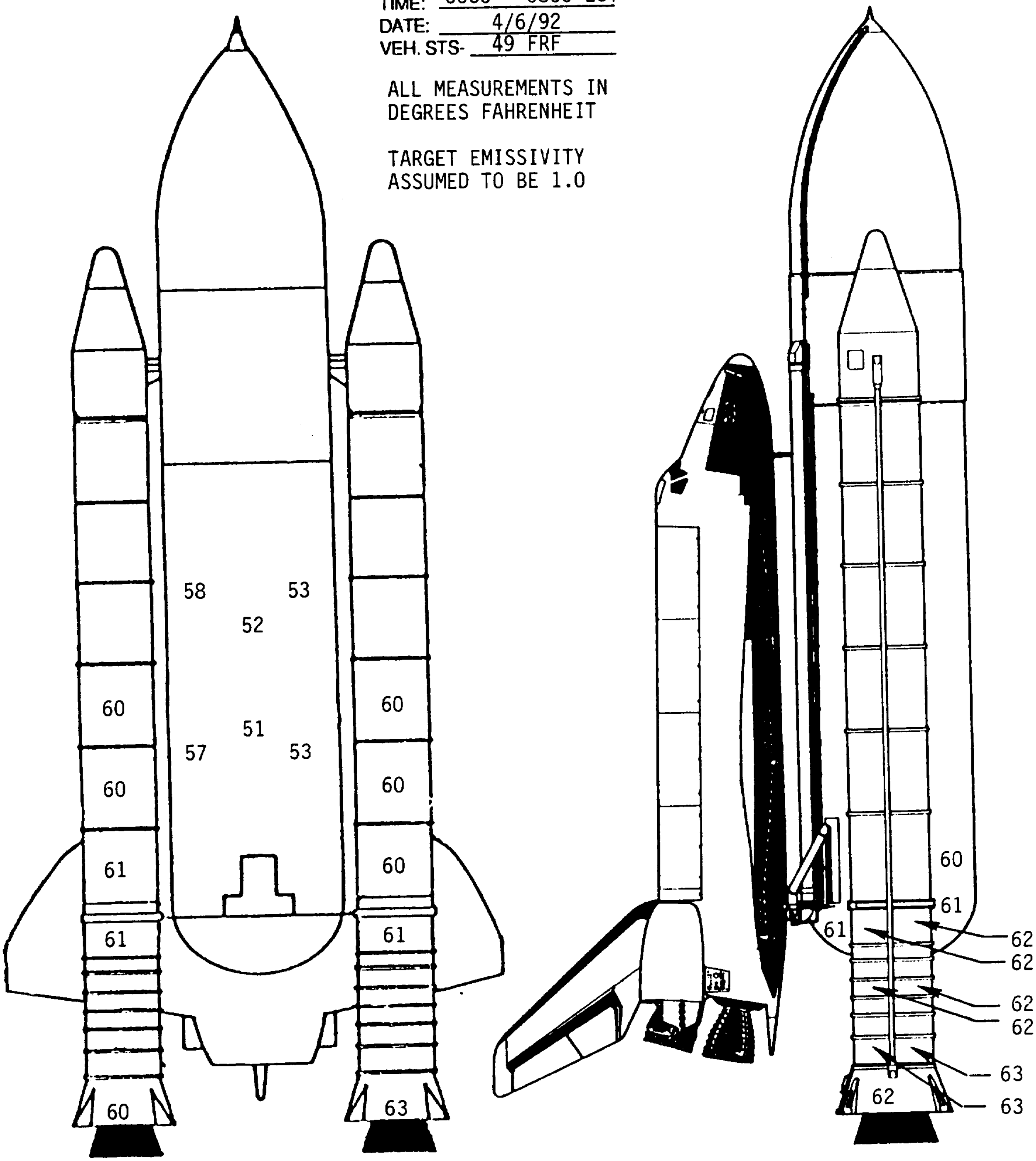
EGG/V 343D

Figure 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0630 - 0800 EST
DATE: 4/6/92
VEH. STS- 49 FRF

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



FGG/V 343C

The intertank TPS acreage was dry. Very small frost spots were present in the -Y-Z quadrant stringer valleys at both LH2 and LO2 tank-to-intertank flanges. No unusual vapors or ice/frost formations were present on the ET umbilical carrier plate. The only TPS anomaly on the intertank consisted of a crack in the foam (-Y-Z quadrant) in the first stringer valley between the -Y thrust panel and the GUCP beginning at the intertank-to-LH2 tank flange and propagating forward. The crack was approximately 18-20 inches in length, 1/4-inch wide with no offset, and was not filled with ice or frost. The portable STI measured surface temperatures that averaged 62 degrees F.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that ranged from 51 to 59 degrees F.

There were no anomalies on the bipods, bipod jack pad closeouts, PAL ramp, cable tray/press line ice/frost ramps, longerons, thrust struts, manhole covers, or aft dome apex. Some ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joints. A suspect crack 6 inches long appeared in the -Y vertical strut cable tray forward facing surface at the tank acreage interface with possible ice/frost in the crack. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry.

Typical amounts of ice/frost were present in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and SSME firing.

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Isolated ice/frost formations were present on the outboard and top sides of the LH2 ET/ORB umbilical purge barrier. Ice/frost fingers 3-5 inches in length had formed on the pyro canister and plate gap purge vents. Ice/frost had formed on the aft pyrotechnic canister bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. (The problem exists through end item EI-66. The mold will be changed to add more foam for EI-67 and subs). Normal venting of helium purge gas had occurred during tanking, stable replenish, and SSME firing. There were no unusual vapors emanating from the umbilicals nor any evidence of cryogenic drips. A ring of frost had formed on the cable tray vent hole.

A 4-inch diameter ice/frost formation with venting (blowing) purge gas was present on the 17-inch flapper valve actuator access port foam plug forward (top) corner. Ice and frost accumulations on the aft side of the LH2 feedline were the result of the cold purge gas impingement. The ice and frost formations were acceptable for the FRF per NSTS-08303. MPS evaluated the venting/blowing purge gas and deemed the condition acceptable for the firing.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle with no flight hardware contact or TPS damage.

The summary of Ice/Frost Team observations/anomalies consisted of 3 OTV recorded items:

Anomaly 001, assessed by the Ice Team on the pad, documented an ice/frost formation with blowing (venting) purge gas on the forward (top) corner of the LH2 umbilical 17-inch flapper valve torque tool access port TPS plug closeout. The ice/frost formation was acceptable per NSTS-08303. The venting/blowing purge gas was evaluated by MPS and deemed acceptable for the FRF.

Anomaly 002 documented a TPS crack in the intertank foam (-Y-Z quadrant) in the first stringer valley between the -Y thrust panel and the GUCP beginning at the LH2 tank-to-intertank flange and propagating forward. The crack was approximately 18-20 inches in length, 1/4-inch wide with no offset, and was not filled with ice or frost. IPR 49V-0314 was upgraded to a PR and dispositioned to use-as-is based on experience with similar TPS cracks at this location.

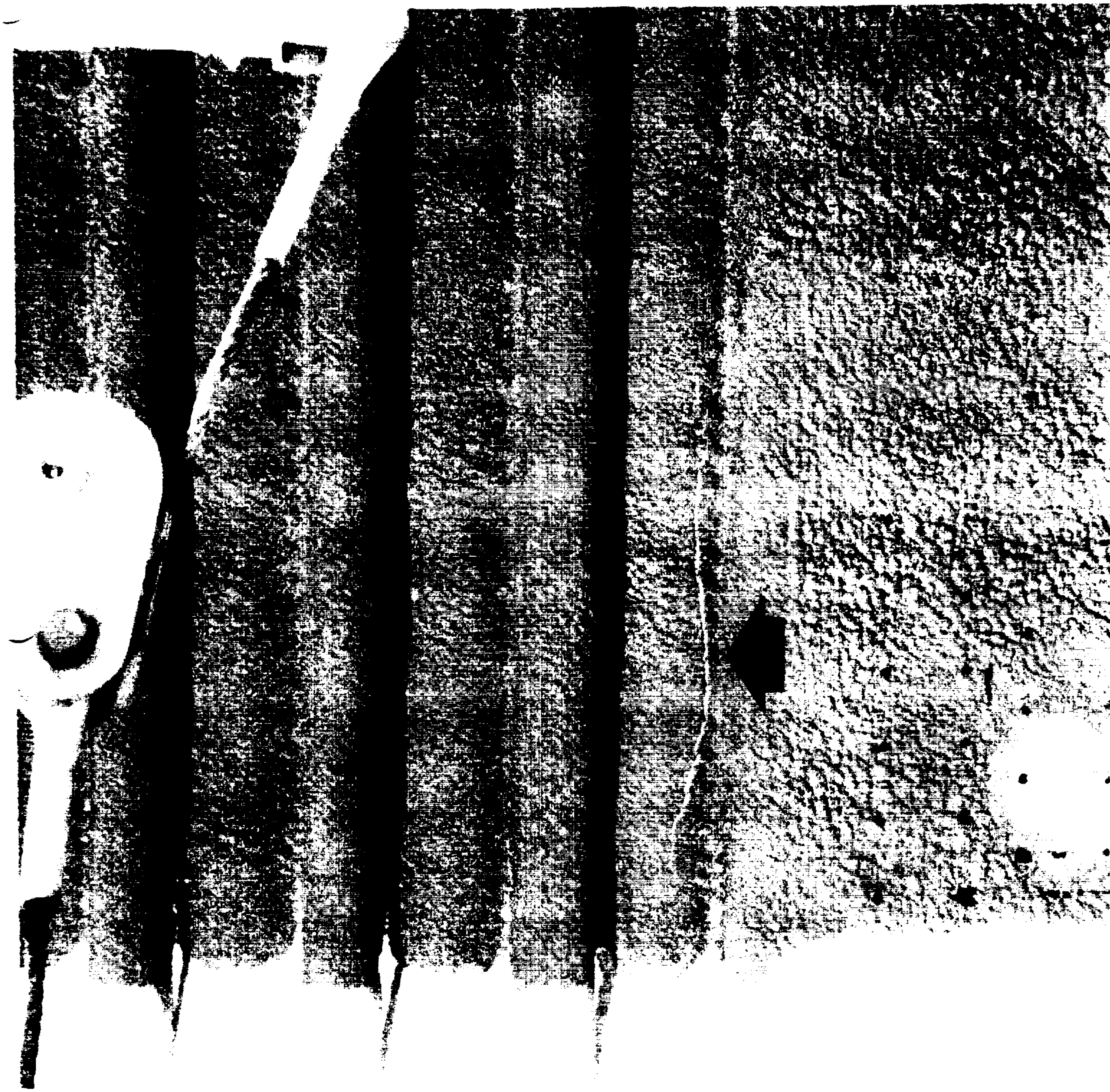
Anomaly 003 recorded a suspect crack in the -Y vertical strut cable tray forward facing surface at the tank acreage interface with possible ice/frost in the crack. An inspection will be performed after the FRF.

FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch. There was no debris on the MLP deck or in the SRB holddown post areas.

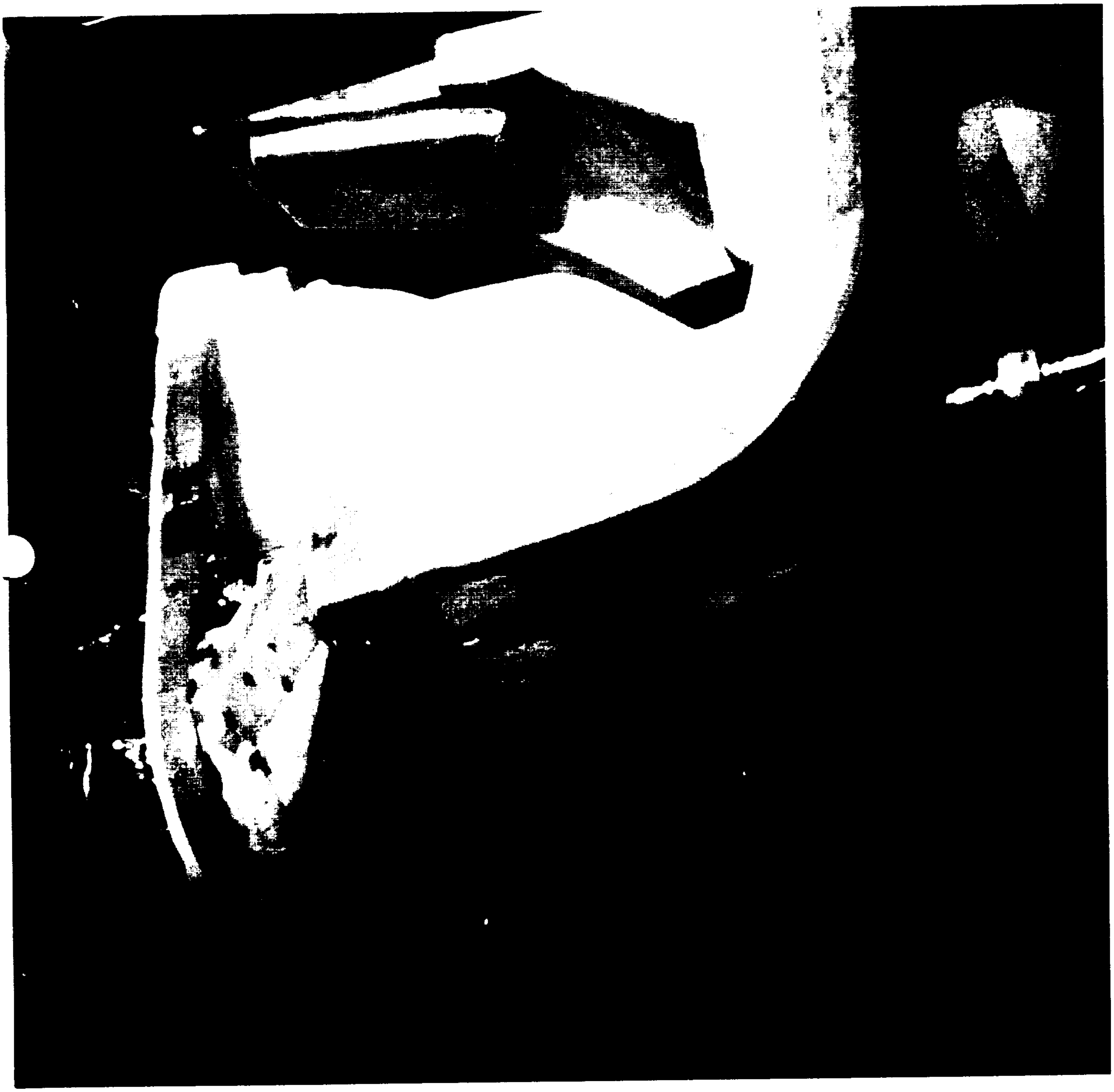
No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds. There was no apparent leakage anywhere on the GH2 vent line or GUCP. The GH2 vent line modification prevented ice from forming, but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. No icicles had formed on the GOX vent ducts.

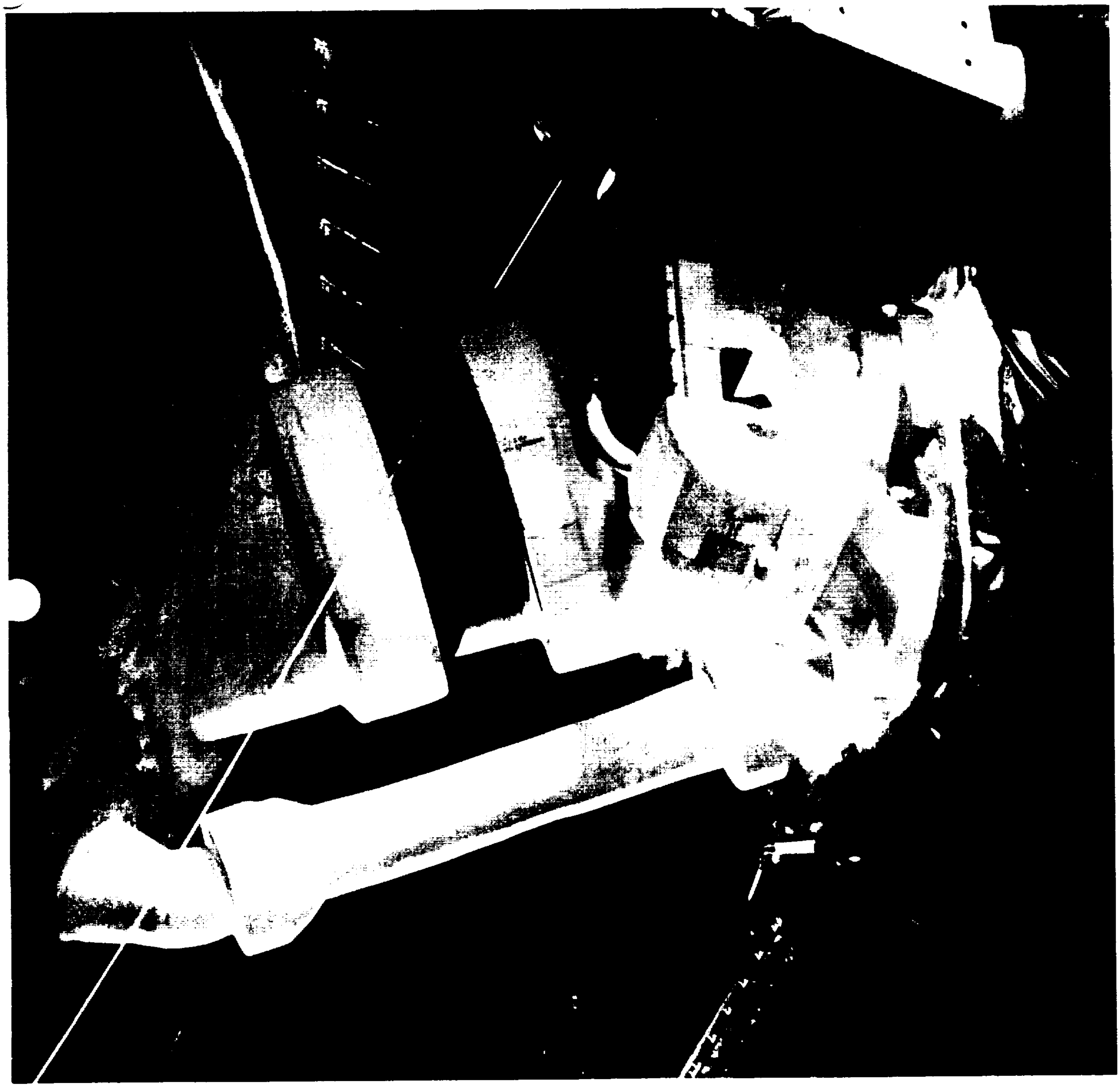


Thermal stresses caused a crack in the intertank TPS (-Y-Z quadrant) in the first stringer valley adjacent to the -Y thrust panel beginning at the LH2 tank-to-intertank flange and propagating forward. The crack was 18-20 inches long, 1/4-inch wide with no offset, and was not filled with ice or frost.

Typical amounts of ice had formed in the LO2 feedline bellows

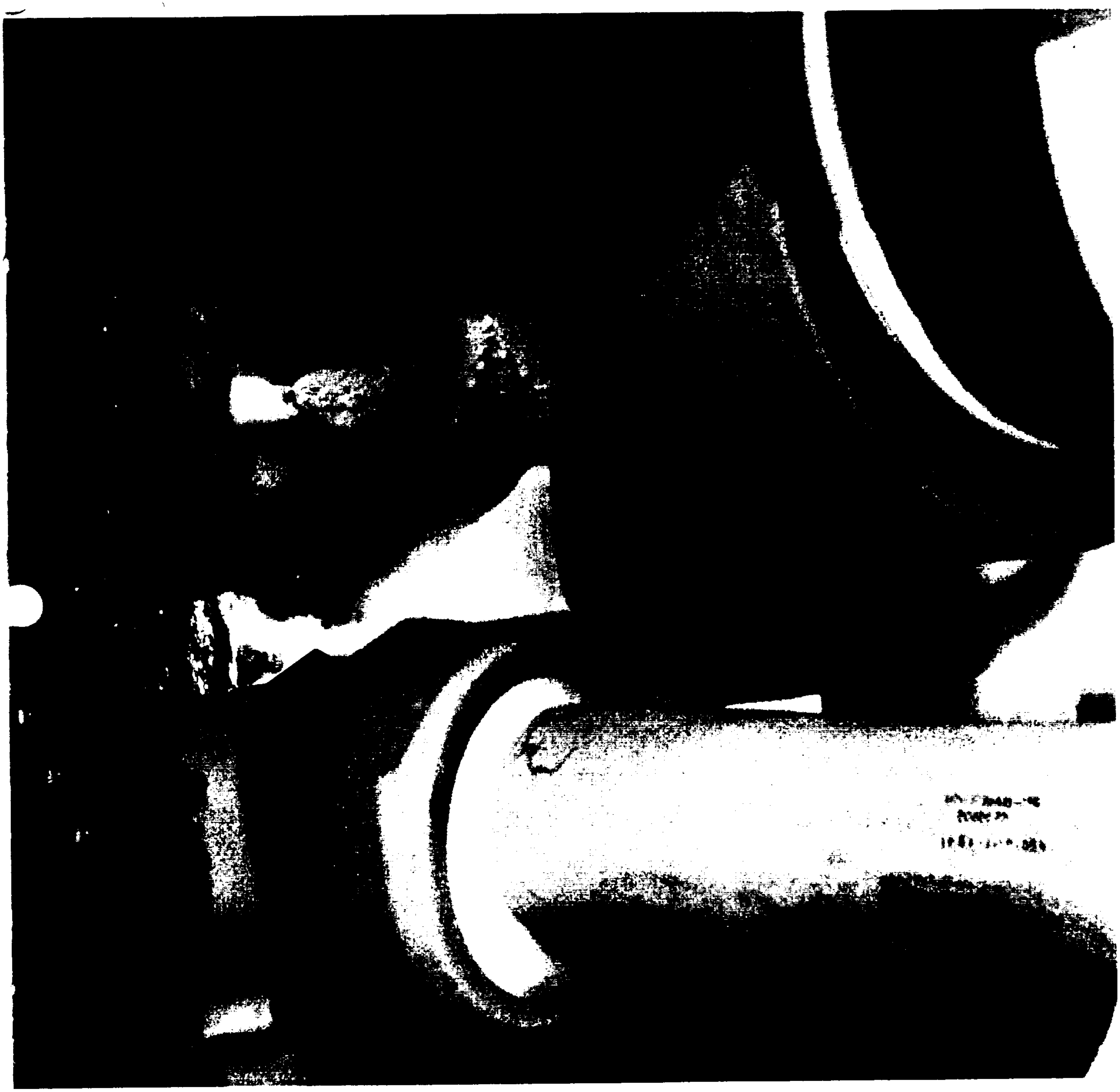


No anomalies were visible on the LO2 ET/ORB umbilical



Ice/frost accumulations on the top and outboard sides of the LH2 ET/ORB were umbilical typical. There were no unusual vapors emanating from the umbilical nor any evidence of cryogenic drips.

Ice/frost had formed on the thin TPS around the aft pyrotechnic canister closeout and bondline. A 4-inch ice/frost formation with venting (blowing) purge gas was present on the 17-inch flapper valve actuator access port foam plug forward corner.



Ice and frost accumulations on the aft side of the LH2 feedline were the result of cold purge gas impingement from the venting (blowing) TPS plug closeout. Ice/frost in the recirculation line bellows, feedline bellows, and purge vents was typical.

3.3 POST DRAIN INSPECTION

A post-drain walkdown of the SSV and the MLP was performed at Pad-39B on 7 April 1992 from 1240 to 1530 hours.

There was no visible TPS damage, such as divots or cracks, on the ET LO2 or LH2 tank acreage. The Ice Team had reported the presence of an 18-20 inch crack in the TPS of the first stringer valley between the -Y thrust panel and GUCP (intertank -Y-Z quadrant) during the T-3 hour inspection. The crack had no offset, no ice/frost, and was not venting. The crack closed during tank warm-up and was not visible during the Post Drain Inspection. Disposition of the IPR accepted the condition for launch since it was typical of structural flexure cracks previously observed and the area was outside the debris zone.

The tumble valve cover was intact. There were no significant anomalies on the -Y side of the nosecone, fairing, louver, and footprint area. Five small areas of topcoat were missing near the grid due to chafing from the GOX vent seal and were faired in with adjacent topcoat.

Both bipod jack pad closeouts were intact. There was no evidence of debonds or cracks.

A hands-on inspection of the LO2 feedline support brackets revealed crushed/damaged BX-250, approximately 3.5"x1", on the outboard side of the XT-1129 attach point at the feedline surface. The damaged area was repaired with PDL foam. Some minor SLA damage occurred on the boomerang bracket.

No cracks were visible in either +Y or -Y thrust strut-to-longeron interfaces. A 4"x3"x1" divot occurred on the +Y longeron closeout near the thrust strut interface. The divot, which exposed the substrate/primer and was most likely caused by a foam defect along with the contraction and expansion of tanking/detanking, was repaired with PDL.

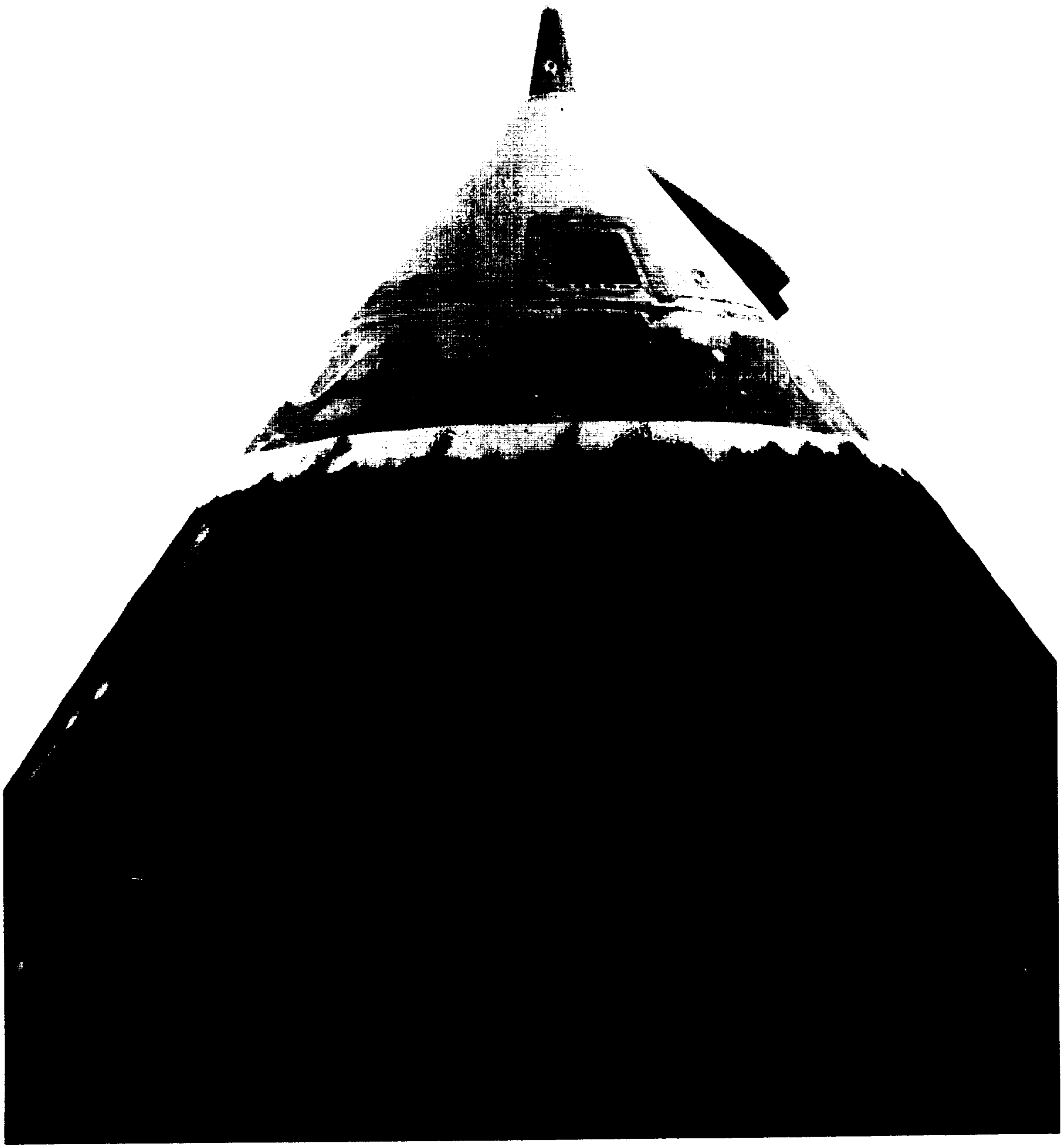
The Ice Team also reported the presence of a 6 inch long crack on the forward face of the -Y vertical strut cable tray. The crack had closed during tank warm-up, but was still visible during the Post Drain Inspection. A stress relief cut in the TPS to allow for structural movement had been deleted by design on this tank at the factory. Since the surface is not cryogenic and sufficient foam remained for ascent aerothermal loads, the crack was accepted for launch.

Neither the LO2 or LH2 ET/ORB umbilicals exhibited TPS anomalies. The 17-inch flapper valve torque tool access port TPS plug was not venting helium purge gas at the time of the Post Drain Inspection, but was replaced prior to the launch countdown since it was defective during the FRF.

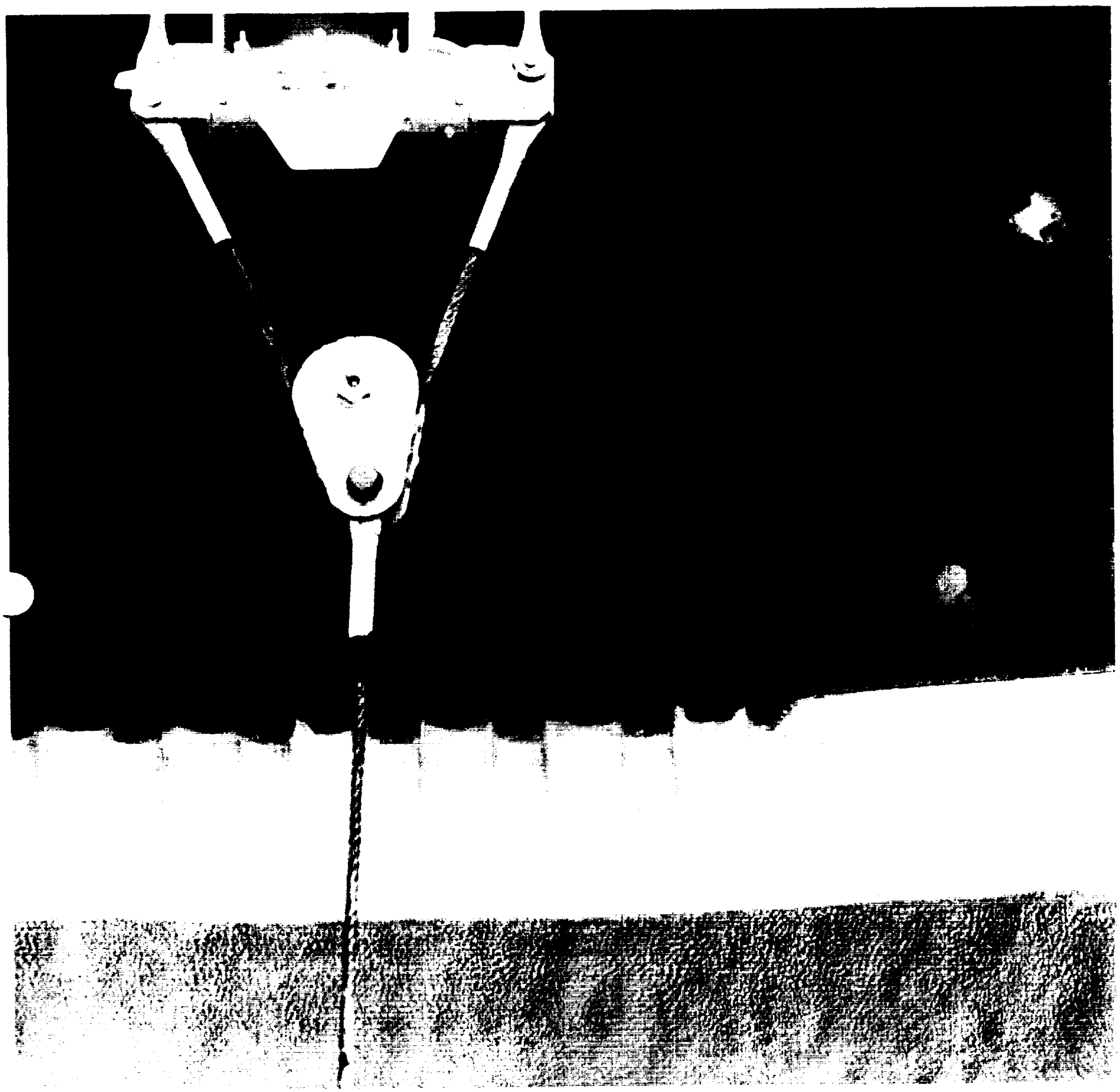
There were no visible TPS anomalies on the LH2 aft dome apex and none of the plug pull repairs were protruding. No TPS defects appeared on the manhole cover closeout rings.

No anomalies were visible on the Orbiter SSME's. Tile material was missing from a 10"x3" area on the body flap stub between SSME #2 and #3 near the body flap hinge. Loss of this material was most likely caused by SSME ignition vibration/acoustics. A 4"x1" orange GSE tile shim, which is not flight hardware, protruded from the +Z side of the body flap near SSME #2. Three areas of tile damage, the largest of which measured 1.5"x1"x0.25", were present outboard of the LO2 ET/ORB umbilical. The damage was not caused by ice falling from the ET LO2 feedline.

No anomalies were visible on the SRB's and the MLP.



There were no significant anomalies on the nosecone, fairing, and louvers. Five small areas of topcoat were missing near the grid due to chafing from the GOX vent seals.



The thermal stress crack that had appeared in the intertank stringer valley adjacent to the thrust panel had closed during tank warm-up and was not visible during the Drain Inspection.

A 4"x3"x1" divot occurred on the +Y longeron closeout near the thrust strut interface. The divot exposed the substrate/primer and was most likely caused by a combination of foam defect and the expansion/contraction of tanking.

Inspection of the LO2 feedline support brackets revealed crushed/damaged BX-250 on the outboard side of the XT-1129 attach point at the feedline surface and some minor SLA damage on the boomerang bracket.

4.0 PRE-LAUNCH BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 6 May 1992 at 1500 hours with the following key personnel present:

S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
B. Davis	NASA - KSC	STI, Ice/Debris Assessment
G. Katnik	NASA - KSC	Lead, Ice/Debris/Photo Team
B. Speece	NASA - KSC	Lead, ET Thermal Protection
B. Bowen	NASA - KSC	ET Processing, Ice/Debris
K. Tenbusch	NASA - KSC	ET Processing, Ice/Debris
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
J. Rivera	NASA - KSC	Lead, ET Structures
M. Bassignani	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
A. Biamonte	NASA - KSC	ET Processing, Ice/Debris
J. Cawby	LSOC - SPC	Supervisor, ET Mech Sys
J. Blue	LSOC - SPC	ET Processing
R. Seale	LSOC - SPC	ET Processing
M. Wollam	LSOC - SPC	ET Processing
W. Richards	LSOC - SPC	ET Processing
M. Jaime	LSOC - SPC	ET Processing
W. Tang	LSOC - SPC	ET Processing
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
S. Otto	MMC - LSS	ET Processing
D. Mason	MMC - LSS	ET Processing
J. Stone	RI - DNY	Debris Assess, LVL II Integ
T. Shawa	RI - LSS	Vehicle Integration
G. Schindler	USBI - LSS	SRB Processing
C. Cooper	MTI - LSS	SRM Processing
R. Hillard	MTI - LSS	SRM Processing

These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

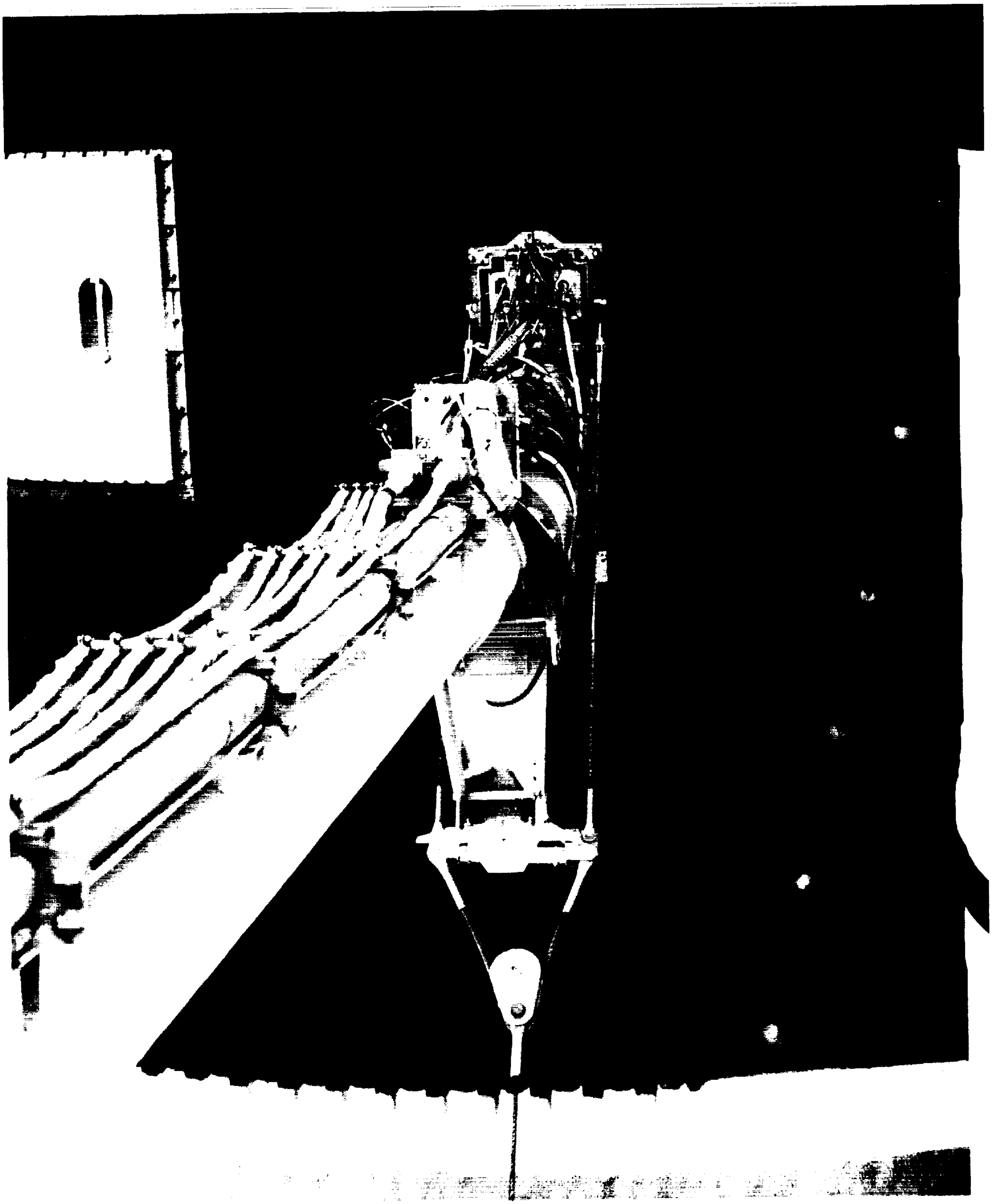
4.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 6 May 1992 from 1645 - 1800 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (FRF/1st flight), ET-43 (LWT 36), and BI-050 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload/launch, temporary hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical until a permanent sensor could be designed and installed. The tygon tubes are intended to remain in place during cryogenic loading and be removed by the Ice Team during the T-3 hour hold.

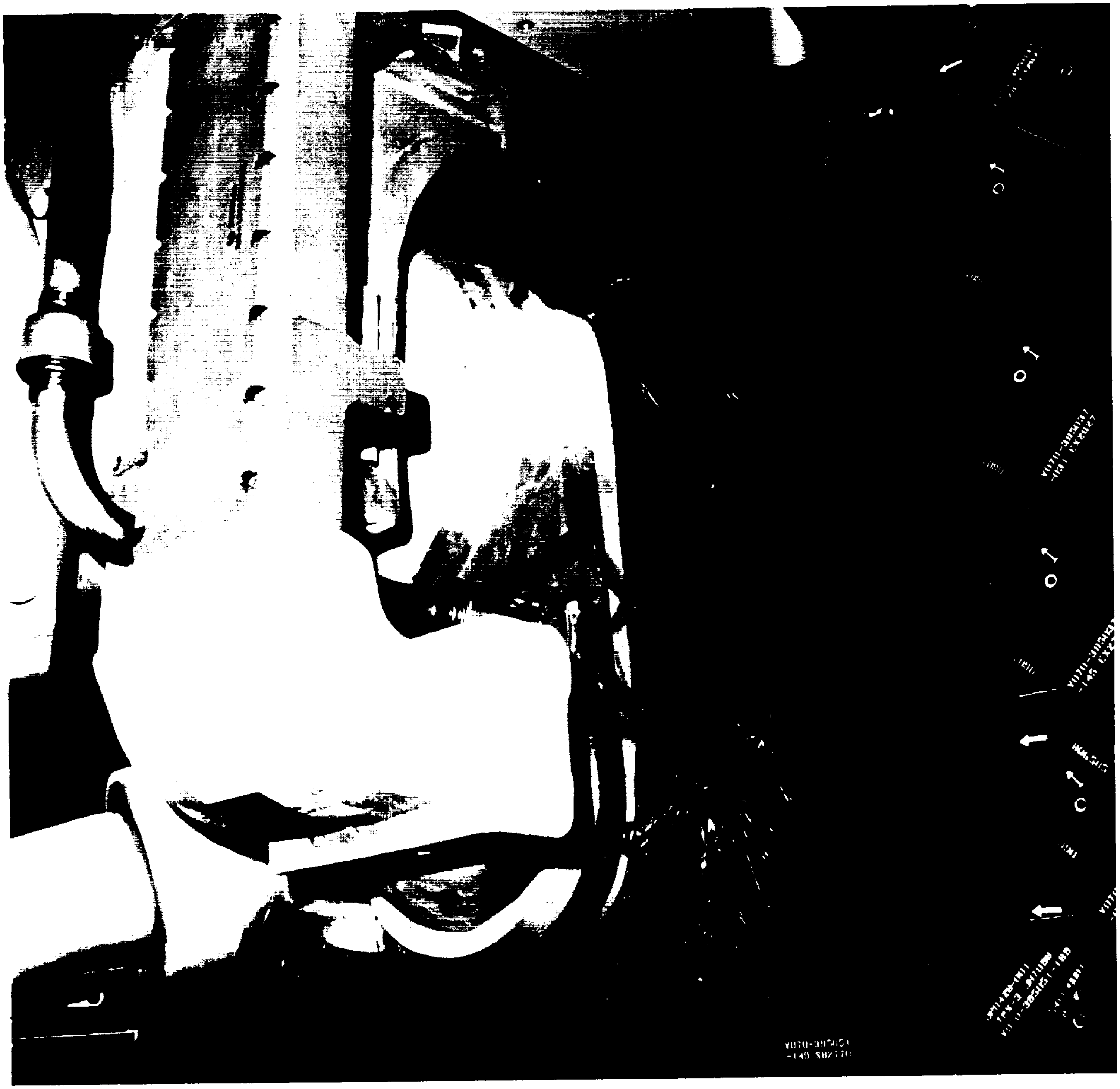
There were no vehicle anomalies.

Bolts were loose on an MLP deck plate west of the LH SRB, on a deck plate east of the RH SRB, on the north side of the LH2 TSM in the BHP 6031 hinged cover, and on the west wall of the HDP #6 haunch. Caps/covers were loose on a J-pipe east of the LH SRB under the water pipe, on a connection box in the northwest corner of the MLP zero level, and on the Portable Purge Unit (PPU) electrical receptacle box. Loose debris, TPS trimmings, tape, and tie-wraps lay on all south holddown post haunches. These discrepancies were either corrected real-time by Pad Operations or were entered in S0007, Appendix K.

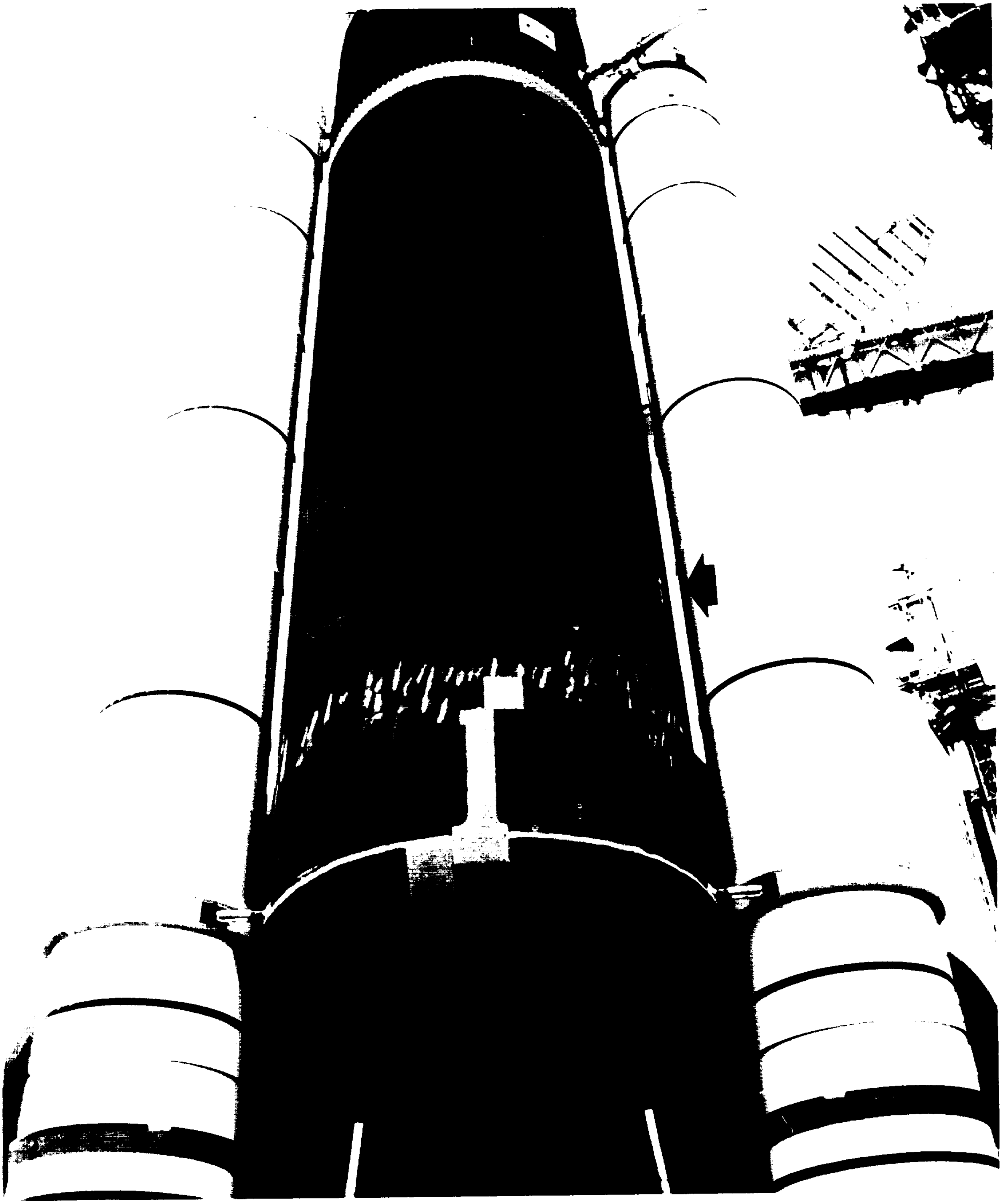


Overall view of the intertank TPS prior to cryogenic loading. A thermal stress crack, which had formed in the first stringer valley adjacent to the thrust panel during the FRF cryogenic loading, had closed up and is not visible when the tank is at ambient temperature.

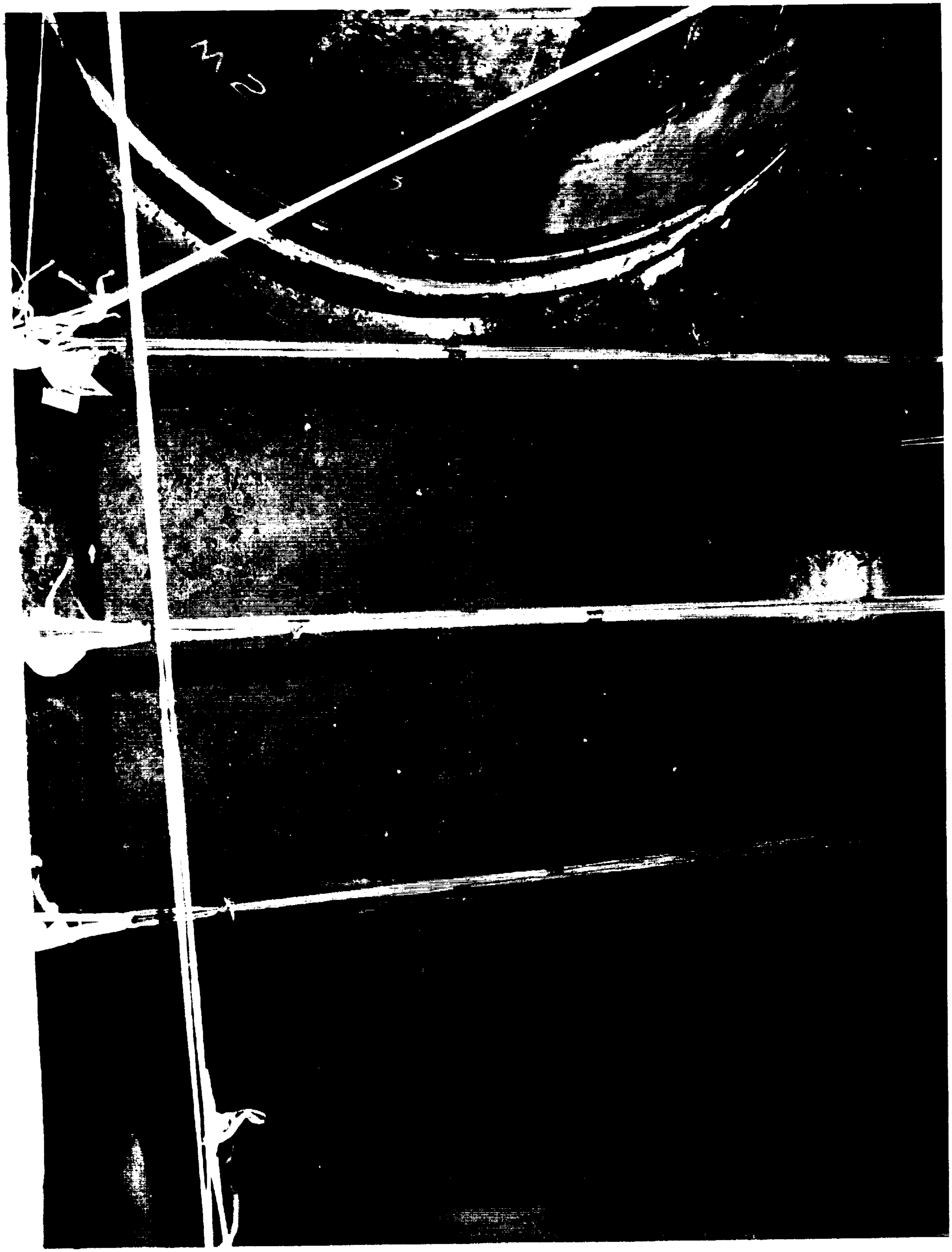
Overall view of the LO2 ET/ORB umbilical. Note installation of the 35mm camera, which photographs the External Tank after separation from the Orbiter.



Overall view of the LH2 ET/ORB umbilical. Note installation of the two 16mm cameras, which provide motion picture separation footage of the LH SRB and the External Tank.



Prior to the Flight Readiness Firing, a piece of rope was observed adhering to the LH2 tank TPS below the GUCP and approximately 85 feet above the MLP deck. Since the rope was on the -Z side and not a debris concern, and would not affect TPS performance, it was not removed prior to launch.



Loose debris, rust, MLP deck scale, and foam trimming in the SRB holddown post haunch areas were removed prior to launch.

5.0 LAUNCH

STS-49 was launched at 7:23:40:00 GMT (19:40:00 local) on 7 May 1992.

5.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 7 May 1992 from 1330 to 1505 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no conditions outside of the established data base. Ambient weather conditions at the time of the inspection were:

Temperature:	64.0 F
Relative Humidity:	77.9 %
Wind Speed:	13.7 Knots
Wind Direction:	330 Degrees

The portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 3 and 4.

5.2 ORBITER

No anomalies were observed on Orbiter tiles, RCC wing leading edge panels, or nosecap. All RCS thruster paper covers were intact. The water spray boiler plugs were properly configured. Light frost was present at the SSME #1 and #2 heat shield-to-nozzle interfaces. The SSME #3 heat shield was dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No GOX vapors originated from inside the SSME nozzles. No condensate was present on base heat shield tiles.

5.3 SOLID ROCKET BOOSTERS

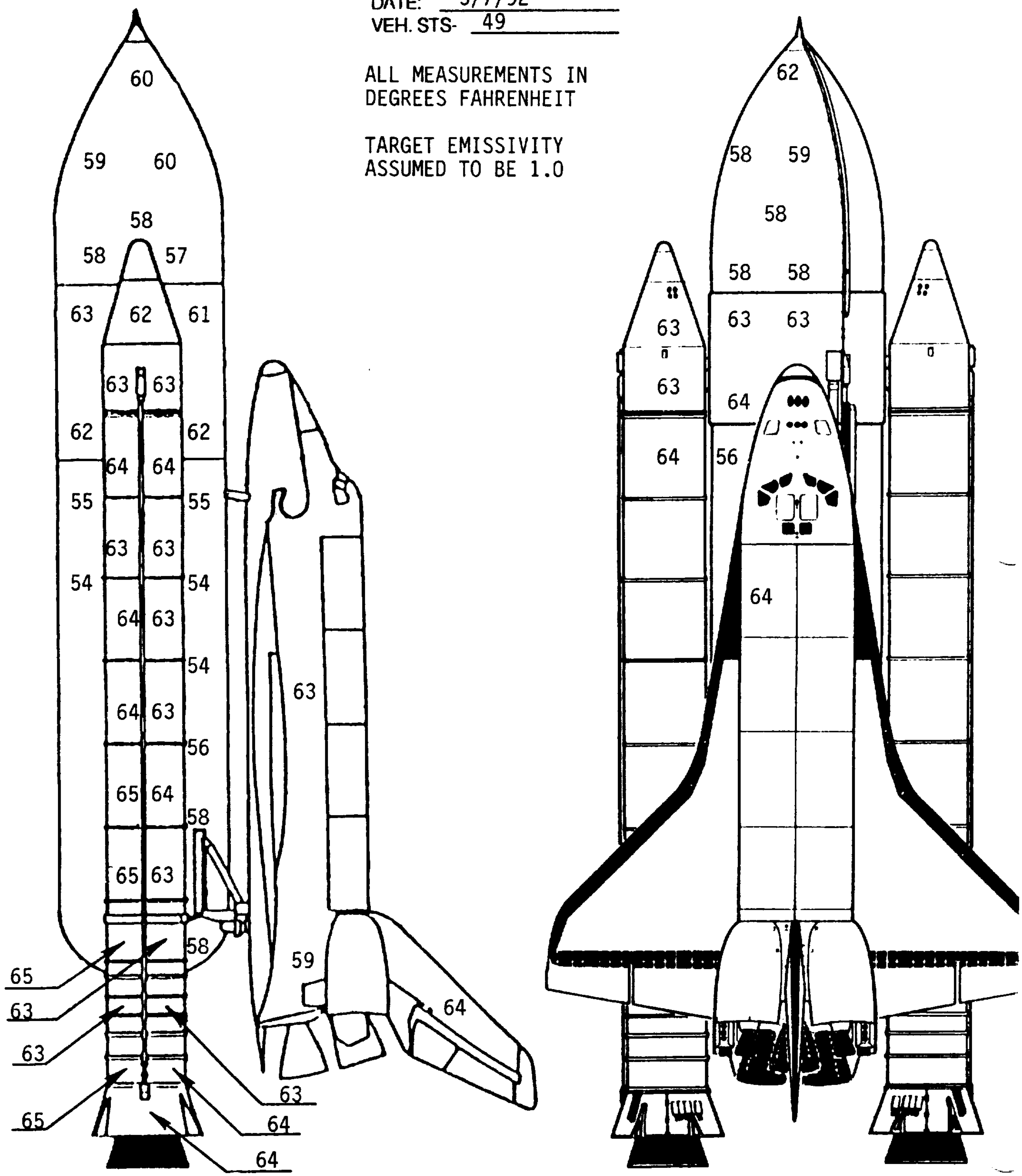
No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures that ranged from 62 to 67 degrees F. In comparison, temperatures measured by the hand-held Cyclops radiometer ranged from 62 to 68 degrees F and the GEI (Ground Environment Instrumentation) measured temperatures that ranged from 64 to 70 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 67 degrees F, which was within the required range of 44-86 degrees F.

Figure 3. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 1330 - 1500 EDT
DATE: 5/7/92
VEH. STS- 49

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



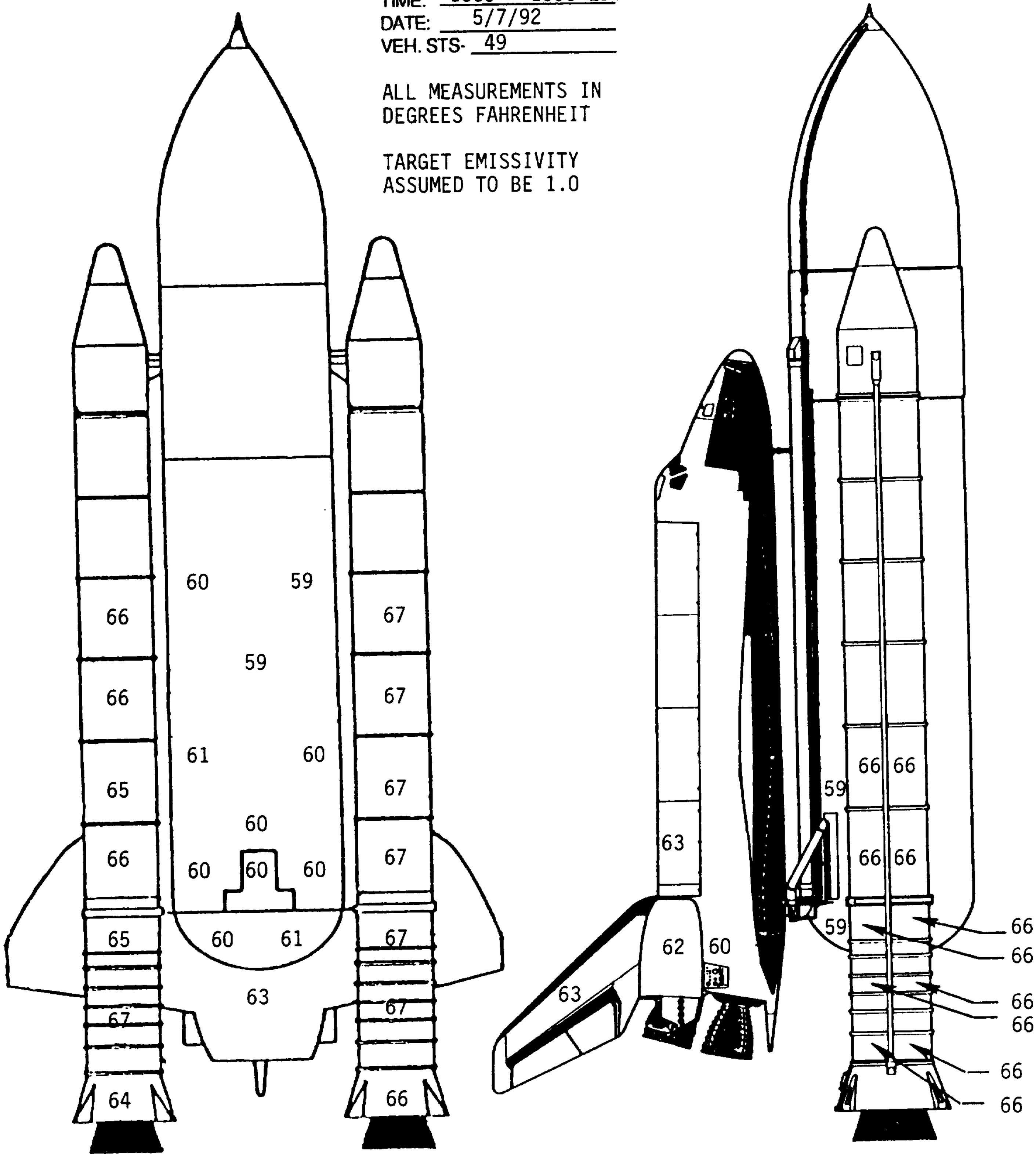
EGG/V 343D

Figure 4. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 1330 - 1500 EDT
DATE: 5/7/92
VEH. STS- 49

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



EGG/V 343C

5.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 1030 to 1940 hours and the results tabulated in Figure 5. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

There was light condensate, but no ice/frost accumulation, on the LO2 tank ogive and barrel sections. There were no TPS anomalies. The tumble valve cover was intact. The pressurization line and support ramps were in nominal configuration. The STI measured surface temperatures that ranged from 59 to 62 degrees F on the ogive and from 57 to 58 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that ranged from 58 to 61 degrees F on the ogive and from 58 to 60 degrees F on the barrel, while SURFICE predicted worst-case temperatures of 54 degrees F on the ogive and 51 degrees F on the barrel.

The intertank TPS acreage was dry. Numerous small frost spots were present in the stringer valleys along the LH2 and LO2 tank-to-intertank flanges in the -Y-Z quadrant. No unusual vapors or ice formations were present on the ET umbilical carrier plate. The only TPS anomaly consisted of a crack in the intertank foam (-Y-Z quardrant) in the first stringer valley between the -Y thrust panel and the GUCP beginning at the LH2 tank-to-intertank flange and propagating forward. The crack was approximately 18-20 inches in length, 1/4-inch wide with no offset, and was not filled with ice or frost. The portable STI measured surface acreage temperatures that averaged 63 degrees and the Cyclops radiometer measured temperatures that averaged 65 degrees F.

There were no LH2 tank TPS acreage anomalies. The rope adhering to the LH2 tank TPS was still present. Light condensate, but no ice or frost, accumulated on the acreage and aft dome. The portable STI measured surface temperatures that ranged from 54 to 60 degrees F on the upper LH2 tank and from 56 to 61 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that ranged from 50 to 55 degrees F on the upper LH2 tank and from 53 to 58 degrees F on the lower LH2 tank. SURFICE predicted temperatures of 48 degrees F on the upper LH2 tank and 55 degrees F on the lower LH2 tank.

There were no anomalies on the bipods, bipod jack pad closeouts, PAL ramp, cable tray/press line ice/frost ramps, longerons, thrust struts, manhole covers, or aft dome apex. A 3-inch diameter ice/frost spot had formed near the end of the PAL ramp at station XT-1528. Two small frost spots had formed on the aft faces of both -Y and +Y ET/SRB cable trays at the tank interface. The PDL repair on the +Y longeron closeout was intact and no ice or frost was present. A crack 6 inches long, first detected during the FRF cryoload, was present in the -Y vertical strut cable tray forward facing surface at the tank

STS- 49 | TEST S0007 LAUNCH | DATE: 7 May 1992 | T-0 TIME: 19:40:00 DATE: 5/7/92 | NASA KSC Ice/Frost/Debris Team

ORBITER 105 | ET 43 | SRB BI-050 | MLP 2 | PAD B

LO2 — CHILLDOWN TIME: 10:25 FAST FILL TIME: 11:04 SLOW FILL TIME: 10:51 REPLENISH TIME: 13:09

LH2 — CHILLDOWN TIME: 10:13 FAST FILL TIME: 10:46 SLOW FILL TIME: 10:22 REPLENISH TIME: 12:59

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
1030	65.00	85.6	60.67	7	328	II	4.13	54.18	0.0023	-0.1080	II	4.13	48.88	0.0037	-0.0794	II	3.22	45.10	0.0038	-0.0520	II	8.61	54.03	0.0044	-0.1782
1045	65.00	84.6	60.34	5	303	II	2.95	51.93	0.0022	-0.0780	II	2.95	45.24	0.0034	-0.0500	II	2.30	40.84	0.0033	-0.0286	II	6.15	51.31	0.0042	-0.1199
1100	65.20	84.8	60.60	7	322	II	4.13	54.24	0.0023	-0.1084	II	4.13	48.95	0.0037	-0.0797	II	3.22	45.19	0.0037	-0.0523	II	8.61	54.08	0.0043	-0.1786
1115	66.80	83.0	61.59	8	333	II	4.72	56.34	0.0022	-0.1314	II	4.72	51.62	0.0038	-0.1023	II	3.68	48.19	0.0039	-0.0707	II	9.84	56.27	0.0042	-0.2212
1130	67.60	80.2	61.43	7	314	II	4.13	55.92	0.0021	-0.1180	II	4.13	50.74	0.0035	-0.0891	II	3.22	47.11	0.0036	-0.0605	II	8.61	55.69	0.0040	-0.1939
1145	66.20	81.4	60.46	9	325	II	5.31	55.93	0.0021	-0.1394	II	5.31	51.58	0.0037	-0.1102	II	4.14	48.35	0.0038	-0.0767	II	11.07	55.94	0.0039	-0.2383
1200	64.40	83.0	59.22	13	297	II	7.67	55.96	0.0020	-0.1814	II	7.67	52.66	0.0037	-0.1516	II	5.98	50.05	0.0040	-0.1089	II	15.99	56.18	0.0036	-0.3248
1215	63.40	83.6	58.42	9	308	II	5.31	53.36	0.0021	-0.1220	II	5.31	48.88	0.0036	-0.0932	II	4.14	45.53	0.0038	-0.0624	II	11.07	53.44	0.0040	-0.2090
1230	64.40	82.6	59.08	6	315	II	3.54	52.01	0.0021	-0.0871	II	3.54	46.03	0.0034	-0.0590	II	2.76	41.96	0.0034	-0.0356	II	7.38	51.64	0.0040	-0.1391
1245	62.40	82.8	57.17	7	306	II	4.13	50.74	0.0021	-0.0890	II	4.13	45.27	0.0034	-0.0610	II	3.22	41.42	0.0034	-0.0365	II	8.61	50.59	0.0039	-0.1463
1300	63.80	82.2	58.35	13	329	II	7.67	55.17	0.0019	-0.1742	II	7.67	51.83	0.0036	-0.1446	II	5.98	49.20	0.0039	-0.1032	II	15.99	55.39	0.0034	-0.3119
1315	64.00	79.0	57.45	8	323	II	4.72	52.46	0.0018	-0.1072	II	4.72	47.57	0.0033	-0.0788	II	3.68	44.02	0.0034	-0.0511	II	9.84	52.39	0.0035	-0.1798
1330	64.40	76.2	56.85	12	334	II	7.08	54.21	0.0014	-0.1561	II	7.08	50.64	0.0031	-0.1270	II	5.52	47.89	0.0034	-0.0893	II	14.76	54.36	0.0026	-0.2763
1345	63.80	75.6	56.05	12	327	II	7.08	53.46	0.0014	-0.1499	II	7.08	49.86	0.0030	-0.1209	II	5.52	47.09	0.0033	-0.0844	II	14.76	53.62	0.0024	-0.2654
1400	63.60	79.6	57.27	13	330	II	7.67	54.42	0.0017	-0.1675	II	7.67	51.06	0.0033	-0.1381	II	5.98	48.43	0.0036	-0.0979	II	15.99	54.63	0.0029	-0.2996
1415	64.80	77.8	57.82	14	333	II	8.26	55.58	0.0014	-0.1878	II	8.26	52.45	0.0032	-0.1581	II	6.44	49.99	0.0036	-0.1141	II	17.22	55.78	0.0025	-0.3380
1430	63.60	80.2	57.48	15	325	II	8.85	55.09	0.0016	-0.1932	II	8.85	52.12	0.0034	-0.1634	II	6.90	49.73	0.0037	-0.1179	II	18.45	55.34	0.0028	-0.3505
1445	63.00	80.0	56.81	14	326	II	8.26	54.17	0.0016	-0.1747	II	8.26	50.99	0.0033	-0.1452	II	6.44	48.46	0.0037	-0.1034	II	17.22	54.41	0.0028	-0.3150
1500	65.00	77.2	57.81	14	333	II	8.26	55.65	0.0014	-0.1886	II	8.26	52.54	0.0031	-0.1588	II	6.44	50.08	0.0035	-0.1147	II	17.22	55.85	0.0024	-0.3392
1515	64.20	76.8	56.87	16	329	II	9.44	55.23	0.0012	-0.2042	II	9.44	52.41	0.0029	-0.1743	II	7.36	50.15	0.0034	-0.1267	II	19.68	55.45	0.0019	-0.3722
1530	63.00	77.8	56.05	13	329	II	7.67	53.42	0.0015	-0.1587	II	7.67	50.03	0.0031	-0.1296	II	5.98	47.37	0.0034	-0.0910	II	15.99	53.63	0.0026	-0.2838
1545	63.20	78.8	56.59	16	342	II	9.44	54.62	0.0014	-0.1980	II	9.44	51.78	0.0031	-0.1682	II	7.04	49.15	0.0036	-0.1152	II	15.84	54.01	0.0028	-0.2875
1600	62.40	78.2	55.59	15	327	II	8.85	53.44	0.0014	-0.1769	II	8.85	50.41	0.0031	-0.1475	II	6.90	47.98	0.0034	-0.1049	II	18.45	53.69	0.0023	-0.3211
1615	64.40	77.2	57.21	16	324	II	9.44	55.52	0.0012	-0.2073	II	9.44	52.71	0.0030	-0.1773	II	7.36	50.45	0.0035	-0.1291	II	19.68	55.74	0.0020	-0.3777
1630	63.60	77.0	56.35	14	333	II	8.26	54.17	0.0013	-0.1745	II	8.26	50.99	0.0030	-0.1452	II	6.44	48.49	0.0034	-0.1035	II	17.22	54.38	0.0023	-0.3143
1645	63.80	75.4	55.97	14	336	II	8.26	54.04	0.0012	-0.1733	II	8.26	50.86	0.0029	-0.1439	II	6.44	48.36	0.0033	-0.1025	II	17.22	54.24	0.0020	-0.3118
1700	64.60	73.8	56.17	15	334	II	8.85	54.76	0.0009	-0.1896	II	8.85	51.78	0.0027	-0.1600	II	6.90	49.43	0.0031	-0.1155	II	18.45	54.96	0.0015	-0.3431
1715	64.60	73.0	55.87	18	326	II	10.62	55.20	0.0005	-0.2233	II	10.62	52.65	0.0023	-0.1932	II	8.28	50.58	0.0029	-0.1417	II	22.14	55.42	0.0007	-0.4105

Figure 5. "SURFICE" Computer Predictions

STS- 49	TEST S0007 LAUNCH					DATE: 7 May 1992	T-0 TIME:19:40:00. DATE: 5/7/92	NASA KSC Ice/Frost/Debris Team
ORBITER 105	ET 43	SRB BI-050	MLP 2	PAD B	LO2 CHILLDOWN TIME: 10:25 SLOW FILL TIME: 10:51 FAST FILL TIME: 11:04 REPLENISH TIME: 13:09	LH2 CHILLDOWN TIME: 10:13 SLOW FILL TIME: 10:22 FAST FILL TIME: 10:46 REPLENISH TIME: 12:59		

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
1730	64.80	71.8	55.61	13	334	II	7.67	54.00	0.0009	-0.1635	II	7.67	50.64	0.0026	-0.1343	II	5.98	48.05	0.0030	-0.0953	II	15.99	54.13	0.0016	-0.2913
1745	64.60	70.0	54.72	13	337	II	7.67	53.40	0.0007	-0.1582	II	7.67	50.02	0.0024	-0.1292	II	5.98	47.42	0.0028	-0.0911	II	15.99	53.52	0.0013	-0.2818
1800	64.20	70.2	54.40	12	337	II	7.08	52.71	0.0009	-0.1437	II	7.08	49.09	0.0024	-0.1150	II	5.52	46.34	0.0028	-0.0797	II	14.76	52.81	0.0015	-0.2536
1815	64.00	69.4	53.89	10	337	II	5.90	51.52	0.0010	-0.1179	II	5.90	47.34	0.0025	-0.0897	II	4.60	44.25	0.0028	-0.0597	II	12.30	51.54	0.0018	-0.2034
1830	64.00	69.4	53.89	13	330	II	7.67	52.66	0.0007	-0.1518	II	7.67	49.25	0.0023	-0.1231	II	5.98	46.63	0.0027	-0.0860	II	15.99	52.79	0.0011	-0.2705
1845	63.60	68.6	53.18	11	332	II	6.49	51.37	0.0008	-0.1249	II	6.49	47.46	0.0023	-0.0967	II	5.06	44.53	0.0027	-0.0650	II	13.53	51.44	0.0015	-0.2182
1900	63.40	69.4	53.30	10	325	II	5.90	50.91	0.0010	-0.1137	II	5.90	46.69	0.0024	-0.0856	II	4.60	43.57	0.0027	-0.0562	II	12.30	50.93	0.0018	-0.1961
1915	63.20	69.0	52.95	10	334	II	5.90	50.61	0.0009	-0.1117	II	5.90	46.39	0.0024	-0.0836	II	4.60	43.26	0.0027	-0.0546	II	12.30	50.64	0.0018	-0.1926
1930	62.60	69.6	52.60	6	313	II	3.54	47.37	0.0013	-0.0647	II	3.54	41.23	0.0024	-0.0376	II	2.76	37.13	0.0025	-0.0179	II	7.38	46.87	0.0026	-0.1015
1940	62.60	70.4	52.91	9	325	II	5.31	49.78	0.0011	-0.0987	II	5.31	45.17	0.0025	-0.0709	II	4.14	41.85	0.0027	-0.0443	II	11.07	49.75	0.0022	-0.1677
AVG.	64.14	76.98	56.82	11.5	NNW		6.78	53.57				6.78	49.63				5.28	46.67				14.04	53.60		

Period of Ice Team Inspection

Figure 5 con't. "SURFICE" Computer Predictions acreage interface. One small frost spot had formed on the -Z side of the +Z manhole cover. Some ice/frost had formed in the ET/SRB cable tray-to-upper strut fairing expansion joints. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry.

Typical amounts of ice/frost were present in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical. Formation of 4-inch ice/frost fingers on the separation bolt pyrotechnic canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Isolated ice/frost formations were present on the outboard and top sides of the LH2 ET/ORB umbilical purge barrier. Ice/frost fingers 3-6 inches in length had formed on the pyro canister and plate gap purge vents. Ice/frost had also formed on the aft pyrotechnic canister bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. (The problem exists through end item EI-66. The mold will be changed to add more foam for EI-67 and subs). Normal venting of helium purge gas had occurred during tanking, stable replenish, and launch. There were no unusual vapors emanating from the umbilicals nor any evidence of cryogenic drips. A ring of frost had formed on the cable tray vent hole. A 4-5 inch diameter ice/frost formation with venting (blowing) purge gas was present on the 17-inch flapper valve actuator access port foam plug forward (top) corner. The ice/frost formation was acceptable for launch per NSTS-08303. MPS evaluated the venting/blowing purge gas and deemed the condition acceptable for launch.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle with no flight hardware contact or TPS damage.

The summary of Ice/Frost Team observations/anomalies consisted of 6 OTV recorded items:

Anomaly 001 documented an ice/frost formation on the ET/ORB LH2 umbilical aft pyro can closeout -Y bondline. The condition was acceptable per NSTS-08303.

Anomaly 002 recorded blowing purge gas with ice/frost formation on the 17-inch flapper valve torque tool access port TPS plug closeout bondline. A blowing gas/loose plug/ice formation assessment was performed. The condition was within the experience data base and was acceptable per the NSTS-08303 criteria.

Anomaly 003 (documentation only) recorded ice/frost formations in the -Y-Z quadrant intertank stringer valleys. Ice/frost spots also formed on the -Y bipod ramp to tank interface aft and outboard side bondlines. These ice and frost formations were acceptable per NSTS-08303.

Anomaly 004 recorded ice/frost formations on both the +Y and -Y vertical strut cable tray doghouse aft sides at the tank interface. The cable tray support ramp at station XT-1528 exhibited an ice/frost spot on the aft side. The ice and frost accumulations were acceptable per NSTS-08303.

Anomaly 005 documented small ice/frost formations on the GOX vent exhaust ducts. Calculations performed by Rockwell-Downey showed falling particles would not impact Orbiter surfaces.

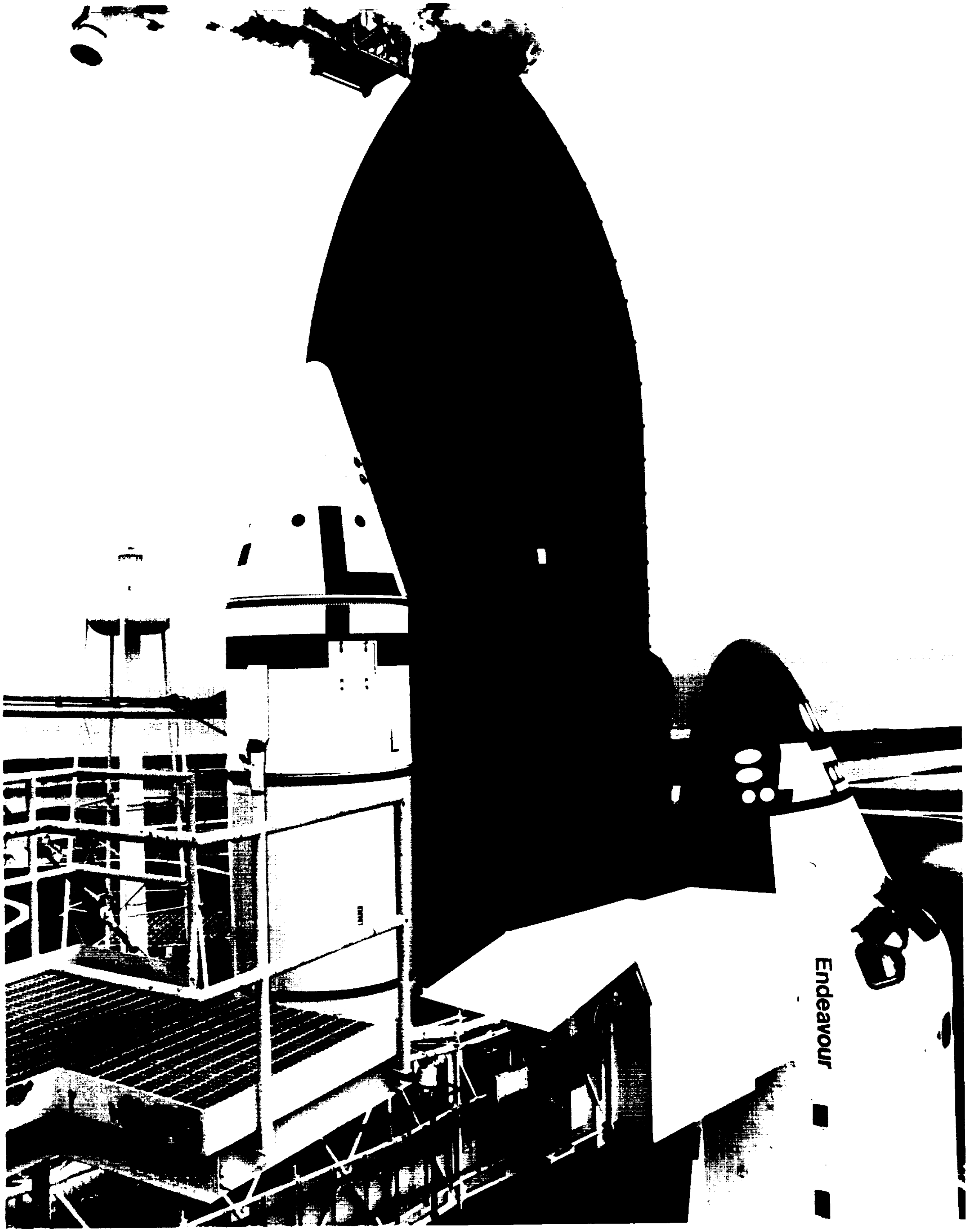
Anomaly 006 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets; in the LH2 recirculation line bellows and burst disks; and on the LO2 and LH2 umbilical purge vents and baggie material. These formations were acceptable per NSTS-08303.

5.5 FACILITY

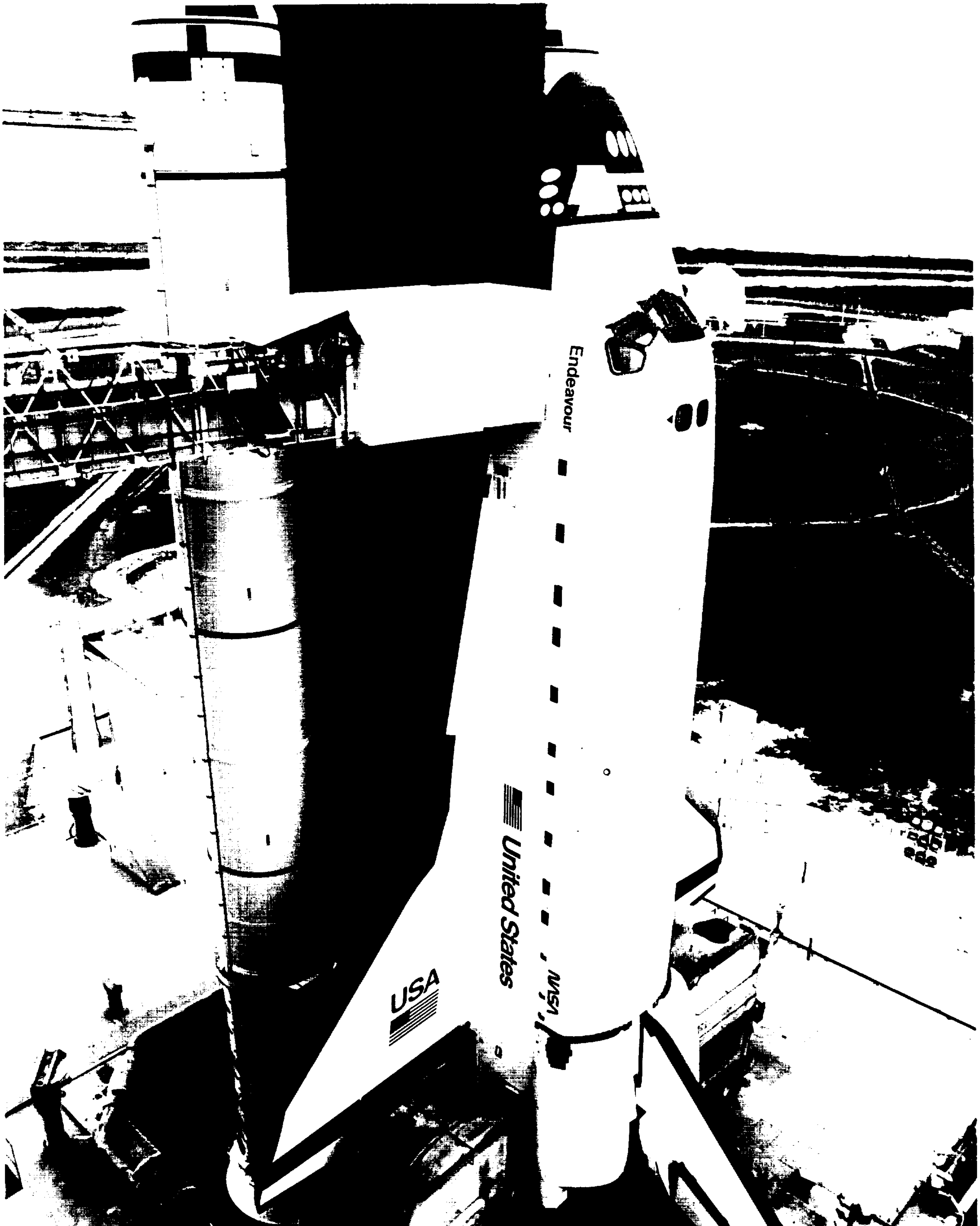
All SRB sound suppression water troughs were filled and properly configured for launch. There was no debris on the MLP deck or in the SRB holddown post areas.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds. There was no apparent leakage anywhere on the GH2 vent line or GUCP. The GH2 vent line modification prevented ice from forming, but some ice/frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. Four small icicles less then 1/2-inch in length had formed on the south GOX vent duct during cryoload, but had melted before launch.



Light condensate, but no ice, frost, or TPS anomalies, were present on the acreage of the LO2 tank ogive and barrel section



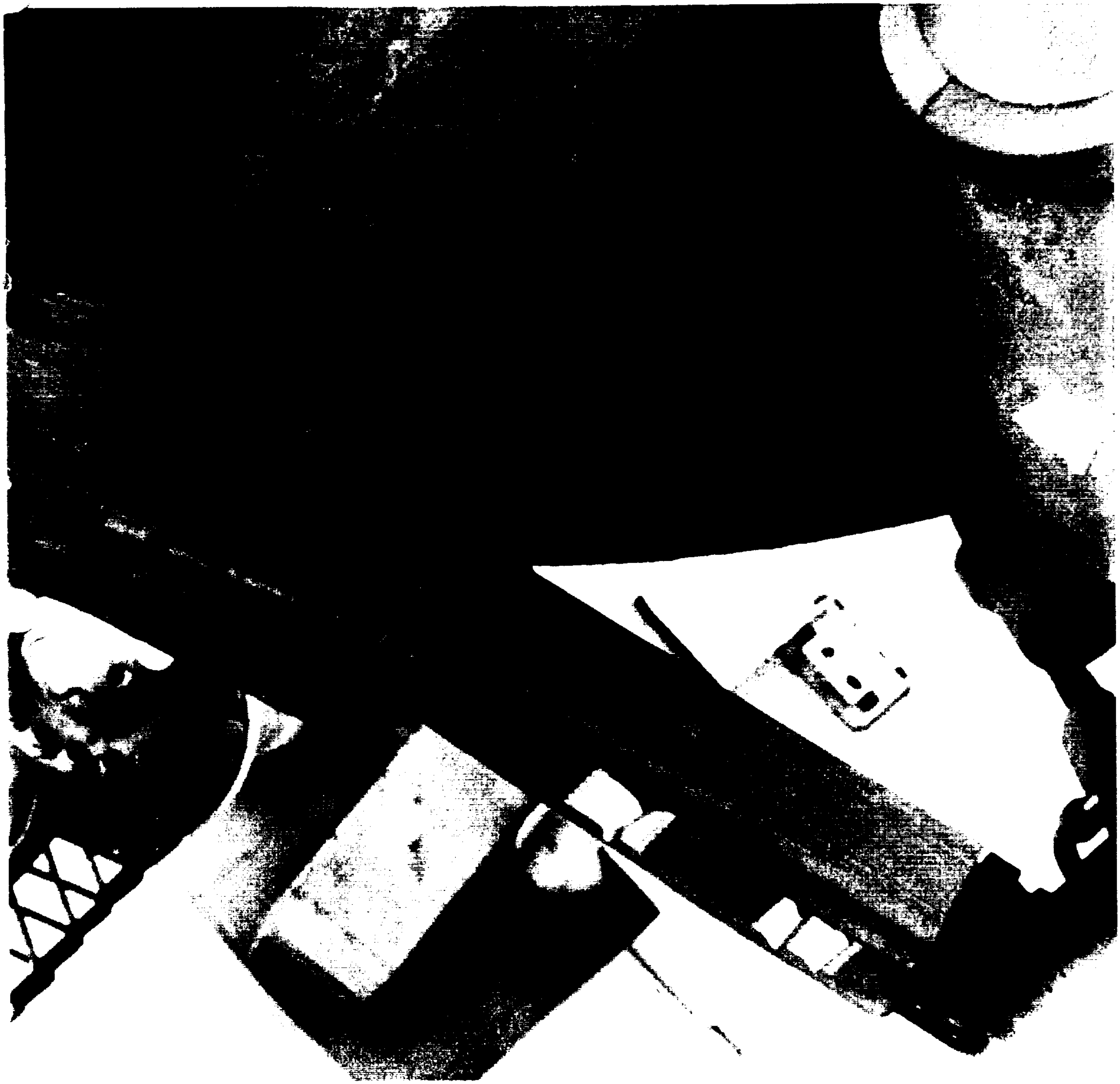
Light condensate, but no ice, frost, or TPS anomalies, were present on the LH2 tank acreage and aft dome. There were no SRB or Orbiter anomalies.

Overall view of the SSME's. Ice/frost had accumulated on the SSME #1 and #2 heatshield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

Ice/frost and condensate were present on the SSME #1 heat shield-to-nozzle interface.

The thermal stress crack in the intertank TPS stringer valley adjacent to the -Y thrust panel reappeared during cryogenic loading. Characteristics of the crack (18-20 inches long, 1/4-inch wide with no offset, and not filled with ice or frost) had not changed since FRF.

Ice/frost formations in the LO2 feedline support brackets and lower bellows were acceptable per the NSTS-08303 criteria.



A crack 6 inches long, first detected during the FRF cryoload, was present in the -Y vertical strut cable tray forward facing surface at the tank acreage interface. A stress relief cut in the TPS to allow for structural movement had been deleted by design.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice and frost formations on the purge vents were typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

View of the LH2 ET/ORB umbilical. There were no unusual vapors emanating from the umbilical nor any evidence of cryogenic drips. Ice/frost accumulations on the umbilical purge vents and on the top/outboard sides of the umbilical were typical.

Ice/frost formations on the lower plate gap purge vent and in the LH2 recirculation line bellows were typical. The 17-inch flapper valve actuator tool access port TPS plug closeout exhibited a blowing purge gas leak and a 4-inch diameter ice formation at the forward corner. The ice formation was acceptable per NSTS-08303. MPS evaluated the venting/blowing purge gas and deemed the condition acceptable for flight.

6.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP and the FSS was conducted on 7 May 1992 from Launch+1-1/2 to 3 hours. No flight hardware or TPS materials were found.

South SRB holddown post erosion was typical. All south HDP shim material was intact, but slightly debonded at the sidewall on HDP #1, #5, and #6. The inboard edge of the bottom shim plate was debonded on HDP #1 and #6. The shim material on HDP #2 was completely debonded. There was no visual indication of a stud hang-up on any of the south holddown posts. There were no ordnance fragments found in the south holddown post stud holes. All of the north post doghouse blast covers were in the closed position and exhibited typical erosion. The SRB aft skirt purge lines were in place but slightly damaged. The SRB T-0 umbilicals exhibited minor damage.

The GOX vent arm, OAA, and TSM's showed the usual minor amount of damage. As observed on OTV prior to launch, an oxygen sensor line was hanging from the white room. The GH2 vent arm was latched on the eighth tooth of the latching mechanism and had no loose cables (static retract lanyard). The GH2 vent line retracted nominally, though the north latch appeared to have contacted the north saddle stabilizer. The damage from this contact was minimal and has occurred on previous launches. The GH2 vent line showed typical signs of SRB plume impingement. The ET intertank access structure also sustained typical plume heating effects.

Damage to the facility appeared to be less than usual and included:

1. A cable tray cover found on the north side of the FSS 235 foot level originated from the cable tray directly above the stairway on that level.
2. Light fixtures on the I/T access arm were detached from support mounts and held only by the electrical cables.
3. OIS handset box cover detached and lying below box on FSS 255 foot level north side.
4. 3/4-inch FSS bolt end with nut attached found on east side of FSS 115 foot level.
5. MLP electrical box, located at the northeast corner of MLP, was missing a cover.

All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

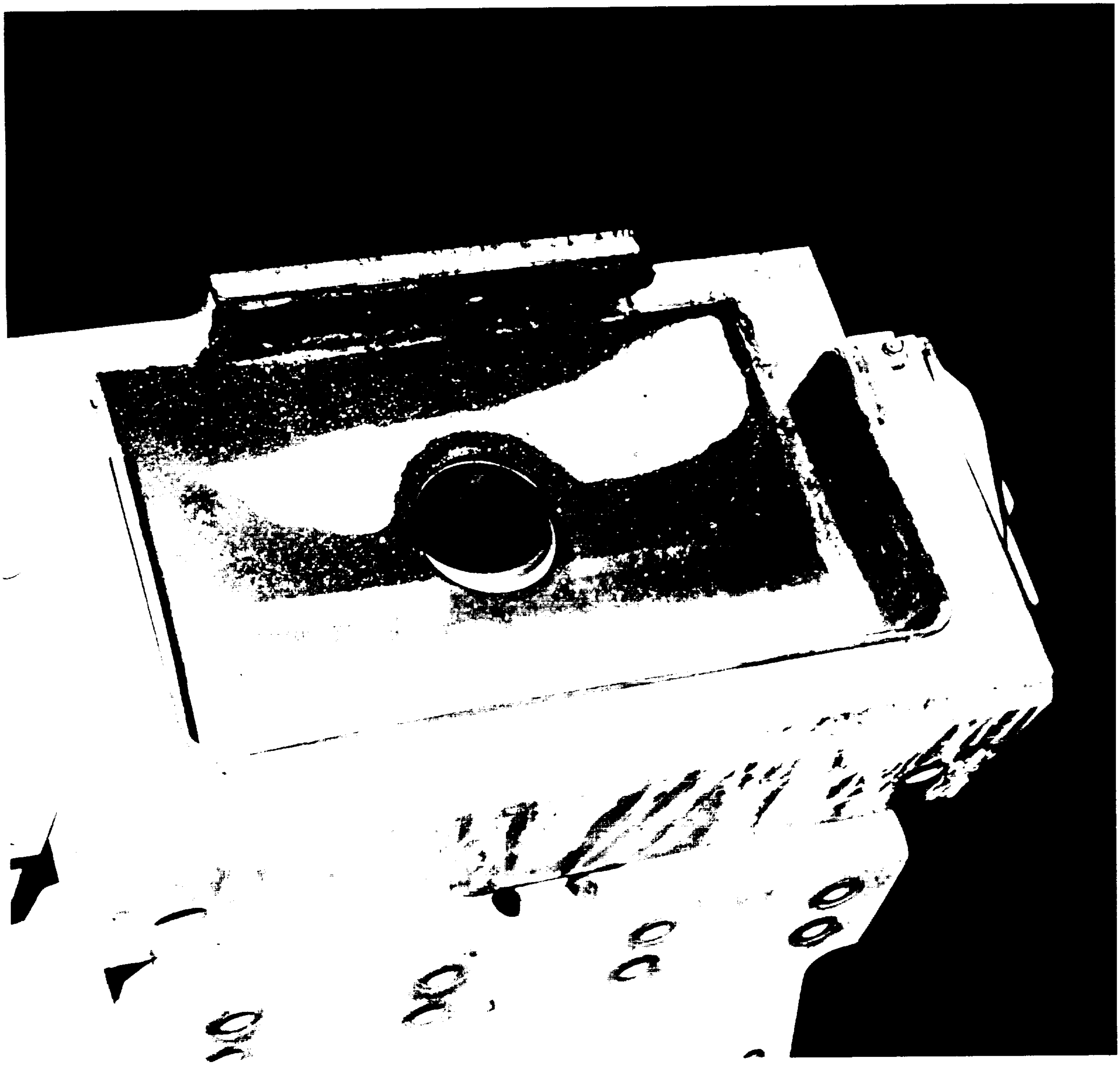
Pad B acreage was inspected on 8 May 1992. The only flight hardware found was two FRSI plugs: one in the boxcar area west of the pad, and the other near the SSME ESP park site. One electrical panel cover was found on the southwest pad slope.

An inspection of the beach from UCS-9 to the Titan complex, the beach road, the railroad tracks, and the water areas around the pad and under the flight path revealed no flight hardware or TPS materials.

MLP-2 was configured with overpressure sensors at the top of both TSM's, at the bottom of both SRB exhaust holes, and at the bottom of the SSME exhaust hole. All sensor readings were consistent with previous launches and within nominal limits.

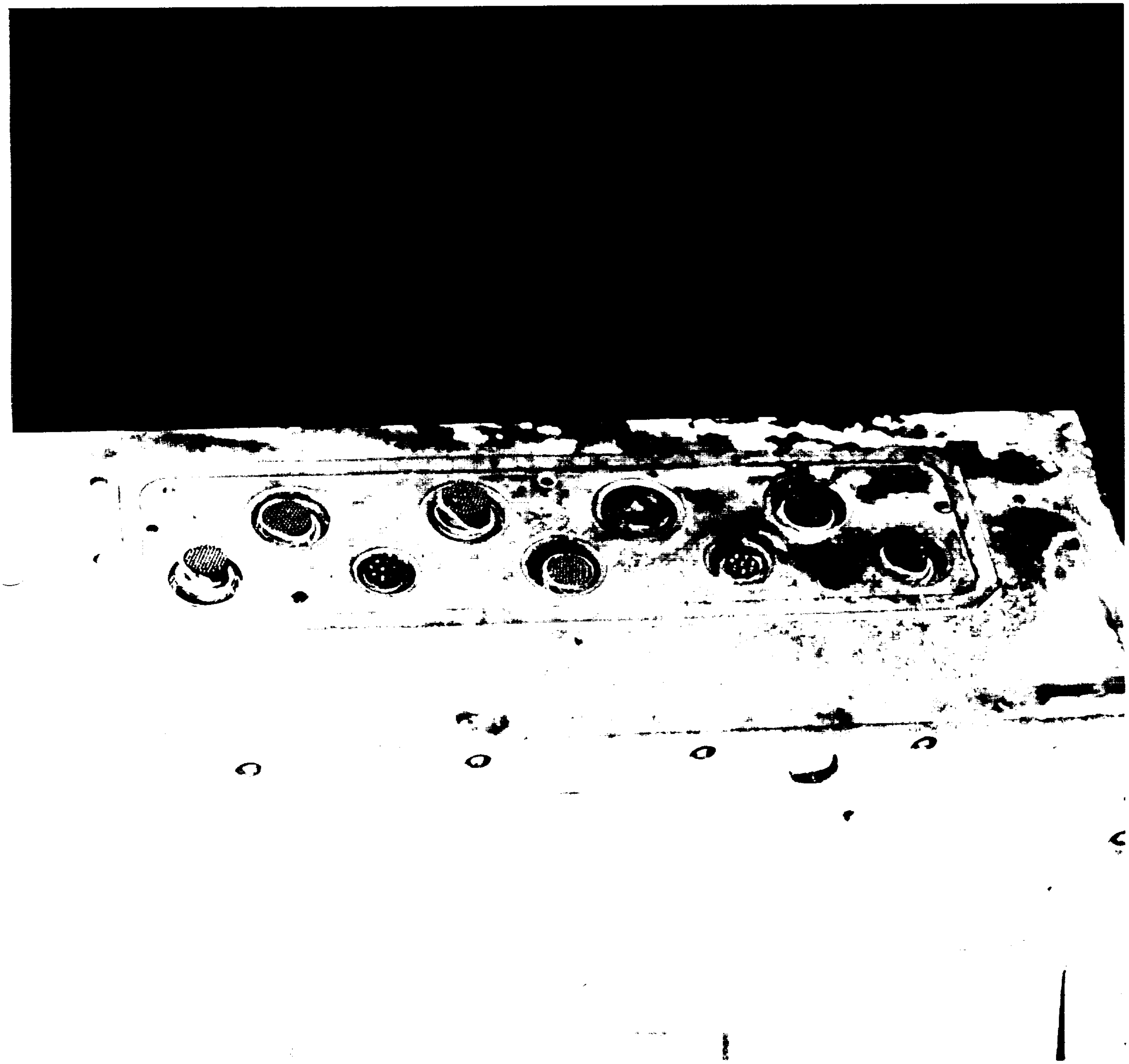
Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). Most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights. A total of 62 particles were imaged in the T+142.5 to 329 second time period. Sixteen of the particles were imaged by only one radar, 30 particles were imaged by two radars, and 16 particles were imaged by all three radars.

Post launch pad inspection anomalies are listed in Section 11.



Plume erosion of the south SRB holddown posts was typical. EPON shim material was intact, but debonded along the sidewalls.

North HDP blast covers were in the closed position and exhibited typical SRB plume erosion effects with some loss of material at the corners.



The SRB T-0 umbilicals sustained minor damage

7.0 FILM REVIEW AND PROBLEM REPORTS

Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 11.

7.1 FLIGHT READINESS FIRING FILM AND VIDEO SUMMARY

A total of 59 film and video items, which included 23 videos, thirty-one 16mm high speed films, and five 35mm large format films, of the OV-105 Flight Readiness Firing were reviewed. There were no significant anomalies.

Film items E-76, 77, 19, 20 showed a fore-and-aft movement (diaphram-like flexing) of the Orbiter base heat shield in the centerline area between the SSME cluster during engine start-up. The movement subsided as the SSME plume stabilized and the Mach diamonds formed. Measurements of E-76 on the S.F.A.T. Film Analyzer showed the amplitude was 1.1 inches. Structures engineering assessed the condition and found no anomaly.

SSME ignition and gimbal profile appeared normal. Flashes appeared in the SSME #2 Mach diamond almost continuously (E-2, 3, 19, 20; OTV 151, 170). Three particles, all approximately 3"x1", fell from an area behind SSME #2 and #3 after SSME ignition but before Mach diamond formation (E-19 frames 2231, 2709; E-20 frames 2215, 2230, 2721; OTV 170). The particles, black on one side and white on the other side, were most likely the pieces of tile material lost from the +Z side of the body flap near the hinge.

The -Y OMS nozzle cover started to come loose at the end of the firing, but remained intact and attached to the vehicle (E-20). Four pieces of coating material fell from the southeast hydrogen Ignitor (on the LO2 TSM) at the start of SSME ignition and during shut down (E-19 frame 5907; OTV 170). The material fell into the SSME plume and did not appear to contact the SSME nozzle.

SSME ignition caused ice/frost on the LH2 ET/ORB umbilical to shake loose. Numerous pieces contacted and were deflected by the umbilical cavity sill, but no tile damage was visible. There were no unusual vapors or cryogenic drips before, during, and after SSME firing (OTV 109).

ET nosecone deflection, as measured from film item E-79 on the S.F.A.T. film analyzer, was 35 inches at the greatest deflection from the "zero" start position. The vehicle returned to the 12-inch mark before starting another "twang" cycle. There were five distinct cycles during SSME firing. SSME shut down caused the vehicle to oscillate between the plus 10-inch and minus 10-inch marks. Total excursion of the ET spike during the FRF was 45 inches (Reference Figure 6).

Excursion of the ET at the GUCP followed a similar pattern, but with smaller amplitudes, to the nosecone deflection (reference Figure 7).

The TSM LO2 T-0 umbilical had been instrumented with position measuring devices to measure the umbilical excursion during cryoload and FRF. Data obtained from the devices and from film item E-21 as measured on the S.F.A.T. film analyzer, showed the umbilical had moved downward during slow fill a maximum of 0.44 inches due to the weight of the ET cryogenics. By the end of slow fill, the ET was contracting from the low temperatures, which caused an upward movement. Upon completion of LH2 fast fill, the umbilical had moved upward a maximum of 2.75 inches above the initial pre-cryoload position. Firing of the SSME's during the FRF caused the umbilical to move upward an additional 9 inches reaching a maximum excursion of 10.7 inches (reference Figure 8).

Firex coverage of the SSME's and base heat shield area after main engine shut down was good. Strong winds prevented a large percentage of Firex water from reaching the ET/ORB LO2 and LH2 umbilicals (OTV 155, 156, 163).

Figure 6. **ET Tip Deflection**

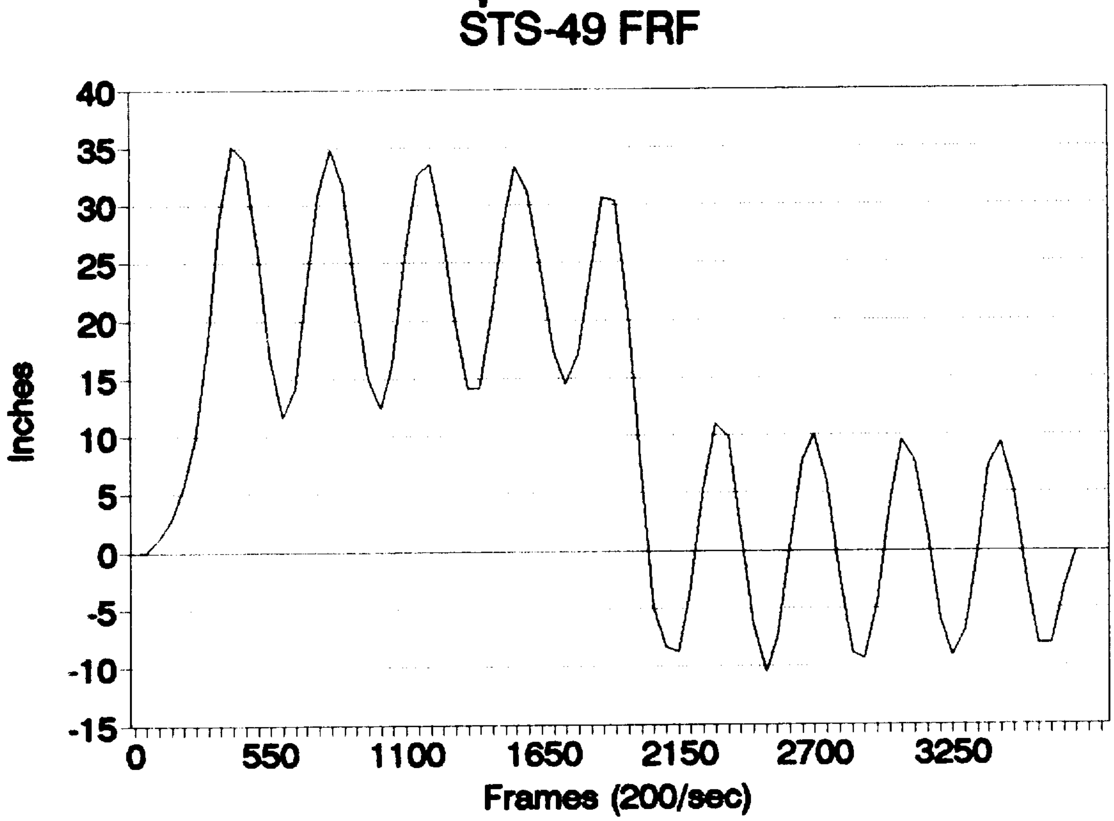
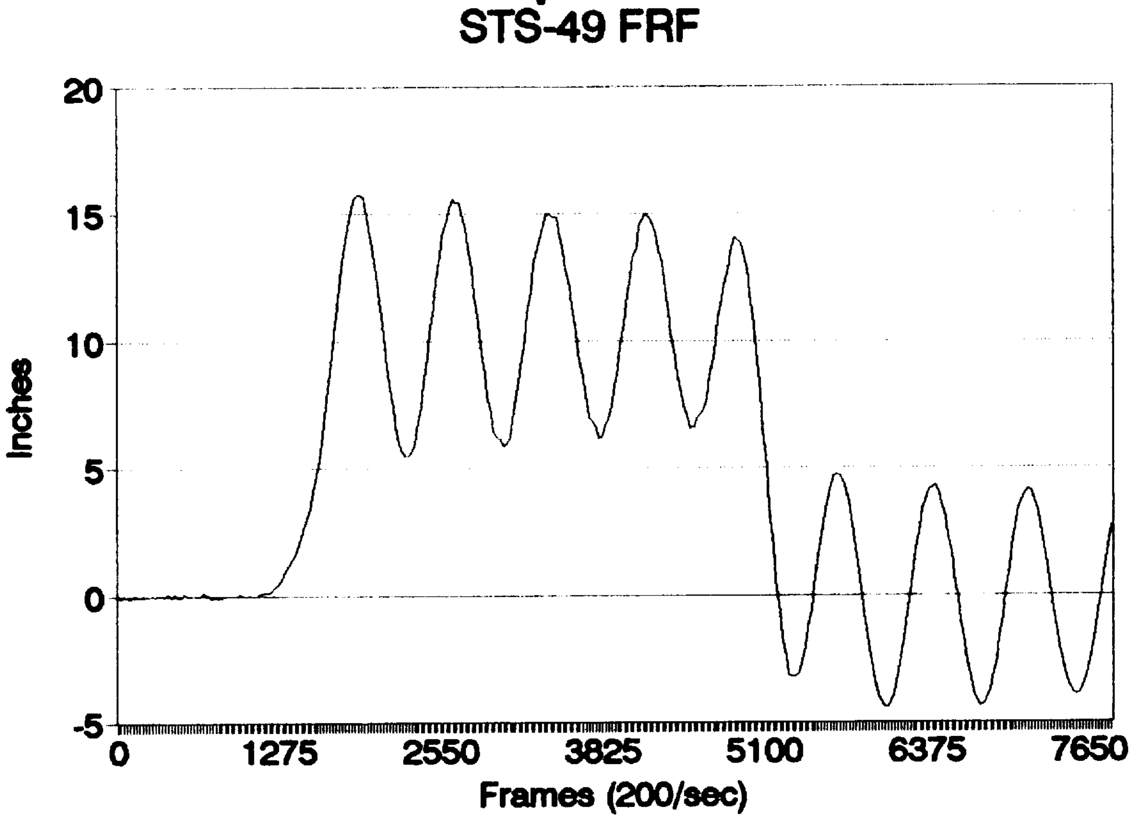
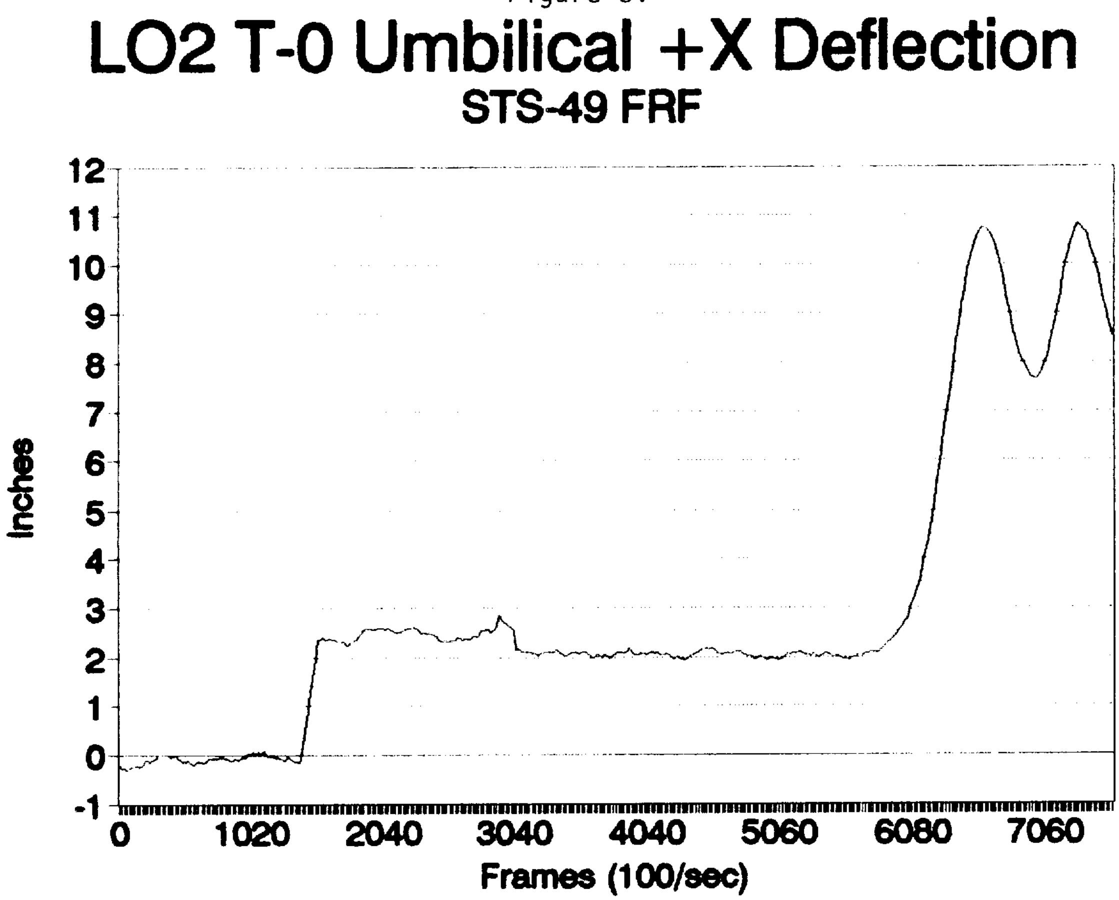


Figure 7. **LH2 Gucp Deflection**



ORIGINAL PAGE
COLOR PHOTOGRAPH

Figure 8.



LO2 T-0 Umbilical +X Deflection
STS-49 FRF
Inches
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
1020
2040
3040
4040
5060
6080
7060
Frames (100/sec)

7.2 LAUNCH FILM AND VIDEO SUMMARY

A total of 110 film and video data items, which included forty-one videos, forty-four 16mm films, twenty 35mm films, four 70mm films, and one 16mm on-orbit film from the LO2 ET/ORB umbilical, were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission.

Film items E-76, 77, 19, 20 again showed a fore-and-aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster during engine start-up. The movement subsided as the SSME plume stabilized and the Mach diamonds formed. Measurements of E-76 on the film analyzer showed the amplitude was 1.1 inches (reference Figure 9).

Research of previous launches and FRF's showed that movement had also occurred on the other Orbiters. Detection of movement in some cases was prevented by lack of lighting, hydrogen ignitor smoke, or camera vibration. Although it now seems evident this movement is common to the Orbiter fleet, structures engineers are interested in measuring the amplitude and frequency of the movement for further analysis.

SSME ignition, Mach diamond formation, and gimbal profile appeared normal. Free burning hydrogen drifted upward to the OMS pods (RSS STI, C/S-2 STI, OTV 151, 170, E-2, 3, 19, 20).

ET nosecone deflection, as measured from film item E-79 on the S.F.A.T. film analyzer, was 35 inches at the greatest deflection from the "zero" start position. The vehicle returned to the 12-inch mark before launch (reference Figure 10).

SSME ignition vibration and acoustics caused the loss of tile surface coating material from three places on the base of the RH RCS stinger (E-19) and from three locations on the Orbiter base heat shield. SSME #2 and #3 engine mounted heat shields exhibited slight side to side motion (white RTV joint referenced to stationary base heat shield tiles) caused by SSME ignition movement/vibration (E-23, 24).

SSME ignition caused numerous pieces of ice/frost to fall from the ET/Orbiter umbilicals, the LH2 feedline bellows, the LH2 recirculation line bellows, and two ice/frost spots on the aft surface of the -Y vertical strut. No damage to Orbiter tiles or ET TPS was visible (OTV 109, 154, 156, 163, 164, E-4). Ice, the largest piece measuring 6"x1" inch, fell from the LO2 feedline upper bellows, but no contact with Orbiter tiles was visible (E-1, 3, 5, 6, 25). There were no unusual vapors or cryogenic drips near the ET/ORB umbilicals during tanking, stable replenish, ignition, or liftoff (OTV 109, 154, 163).

Figure 9.

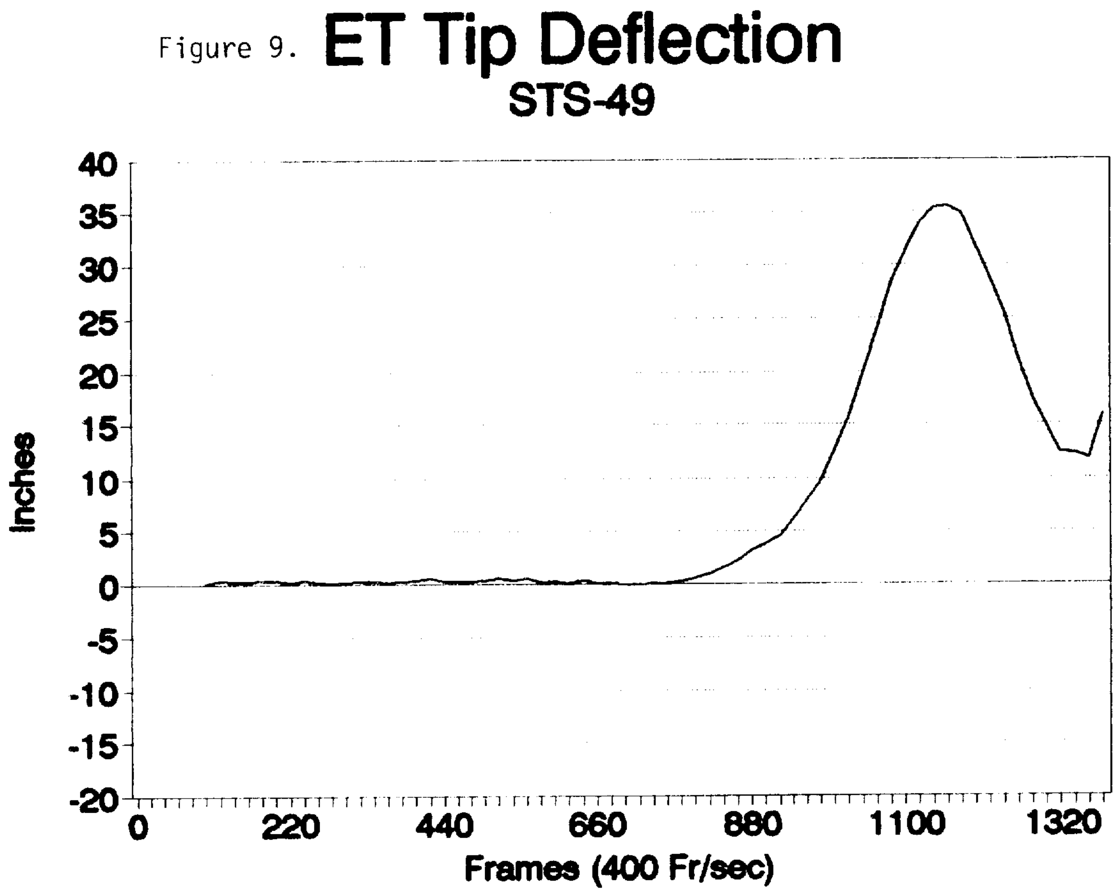
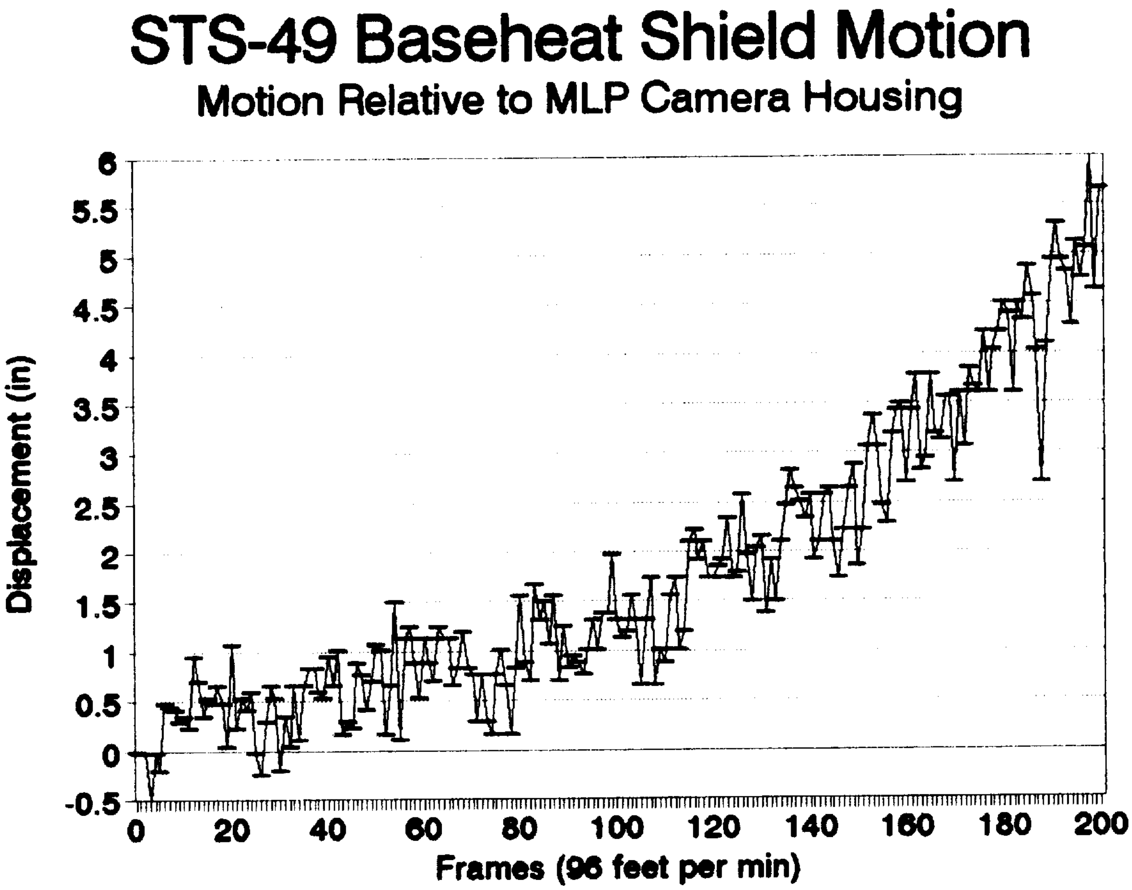

ET Tip Deflection
STS-49
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
Inches
0
220
440
660
880
1100
1320
Frames (400 Fr/sec)

Figure 10



STS-49 Baseheat Shield Motion
Motion Relative to MLP Camera Housing
Displacement (in)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0
20
40
60
80
100
120
140
160
180
200
Frames (96 feet per min)

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 163). The LH2 purge barrier was caught in the TSM door after LH2 T-0 retraction (OTV 170, E-18). Separation of the GUCP from the External Tank was nominal. The GH2 vent arm retracted and latched properly with no rebound. There was no excessive slack in the static retract lanyard (OTV-104, 171, E-33, 41, 42, 48, 50). Film item E-60 confirmed that water flowed properly from all MLP rainbirds.

No stud hang-ups occurred on the SRB holddown posts and no ordnance debris fell from the HDP DCS/stud holes. A piece of instafoam broke off near the LH SRB aft skirt nitrogen purge line (E-13).

Six pieces of ice fell aft from the LH2 umbilical during the roll maneuver. The piece of rope on the -Z side of the External Tank was still attached to the SOFI after tower clear. No anomalies were observed in the area of the ET intertank where the 20-inch stringer valley TPS crack had occurred during cryoload (E-59).

Clusters of particles falling aft of the Orbiter after the roll maneuver were traced to the forward RCS thrusters and were pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings.

White flashes appeared in the SSME plume shortly after the roll maneuver and may be related to atmospheric effects. Two orange streaks occurred in the SSME #1 plume during ascent at approximately 39 and 44 seconds MET (E-212, 220).

Movement of the body flap was less visible than that observed on previous flights (E-212).

One piece of LH SRB thermal curtain tape was loose on the -Z side of the aft skirt (E-212).

Light colored particles fell out of the SRB exhaust plume during ascent and were most likely pieces of SRB propellant (E-207).

ET aft dome charring, plume recirculation, and SRB separation appeared normal. Several instances of plume brightening, which have been observed on previous flights, occurred during tailoff (TV-13, E-205, 218).

7.3 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was not performed by the crew due to dark conditions. OV-105 was equipped to carry umbilical cameras: one 35mm and one 16mm with a 5mm lens. (The other 16mm camera with the 10mm lens had been deleted prior to launch due to an interference problem).

No major vehicle damage or lost flight hardware was observed that would have been a safety of flight concern. Erosion and charring of TPS on the aft surfaces of the LH2 umbilical cable tray and the -Y vertical strut/cable tray was typical. Plume recirculation and aft dome heating caused the usual charring and "popcorning" of the NCFI foam. Plume recirculation was also responsible for the sooting of the LH aft booster, an expected occurrence. Separation of the -Y ET/SRB upper and diagonal struts was nominal. No loss of TPS from the upper strut fairing was visible. No anomalies were observed on the LH SRB segment cases and joints, forward skirt, and frustum after separation from the ET.

The footage of External Tank separation contained little usable data due to the dark conditions.

7.4 LANDING FILM AND VIDEO SUMMARY

A total of 17 film and video data items, which included seven videos, eight 16mm high speed films, and two 35mm large format films, were reviewed.

Orbiter performance in the Heading Alignment Circle (HAC), landing gear deployment, flare, final approach, and touchdown appeared normal. Touchdown of the nose landing gear was smooth. First use of the drag chute, which was deployed just after nose wheel touchdown, was nominal. No vehicle damage or significant tile damage was visible in these views.

LH2 ET/ORB umbilical separation camera showed typical erosion and charring of TPS on the aft surfaces of the umbilical cable tray and -Y vertical strut. Plume recirculation and aft dome heating caused the usual charring and "popcorning" of the NCFI foam.

LH2 ET/ORB umbilical separation camera showed no vehicle damage or loss of flight hardware that would have been a safety of flight concern. Separation of the LH SRB from the External Tank was normal. No loss of TPS from the upper strut fairing was visible.

8.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 11 May 1992 from 0800 to 1130 hours. From a debris standpoint, both SRB's were in excellent condition.

8.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS but had 5 MSA-2 debonds over fasteners (Figure 11). Minor blistering of the Hypalon paint had occurred along the 395 ring. All BSM aero heatshield covers were locked in the fully opened position. However, two (right side) cover attach rings had been bent at the hinge by parachute riser entanglement.

The RH forward skirt exhibited no debonds or missing TPS (Figure 12). The phenolic plates on both RSS antennae were intact. Minor blistering of the Hypalon paint occurred on the systems tunnel cover and around the forward attach point. The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring.

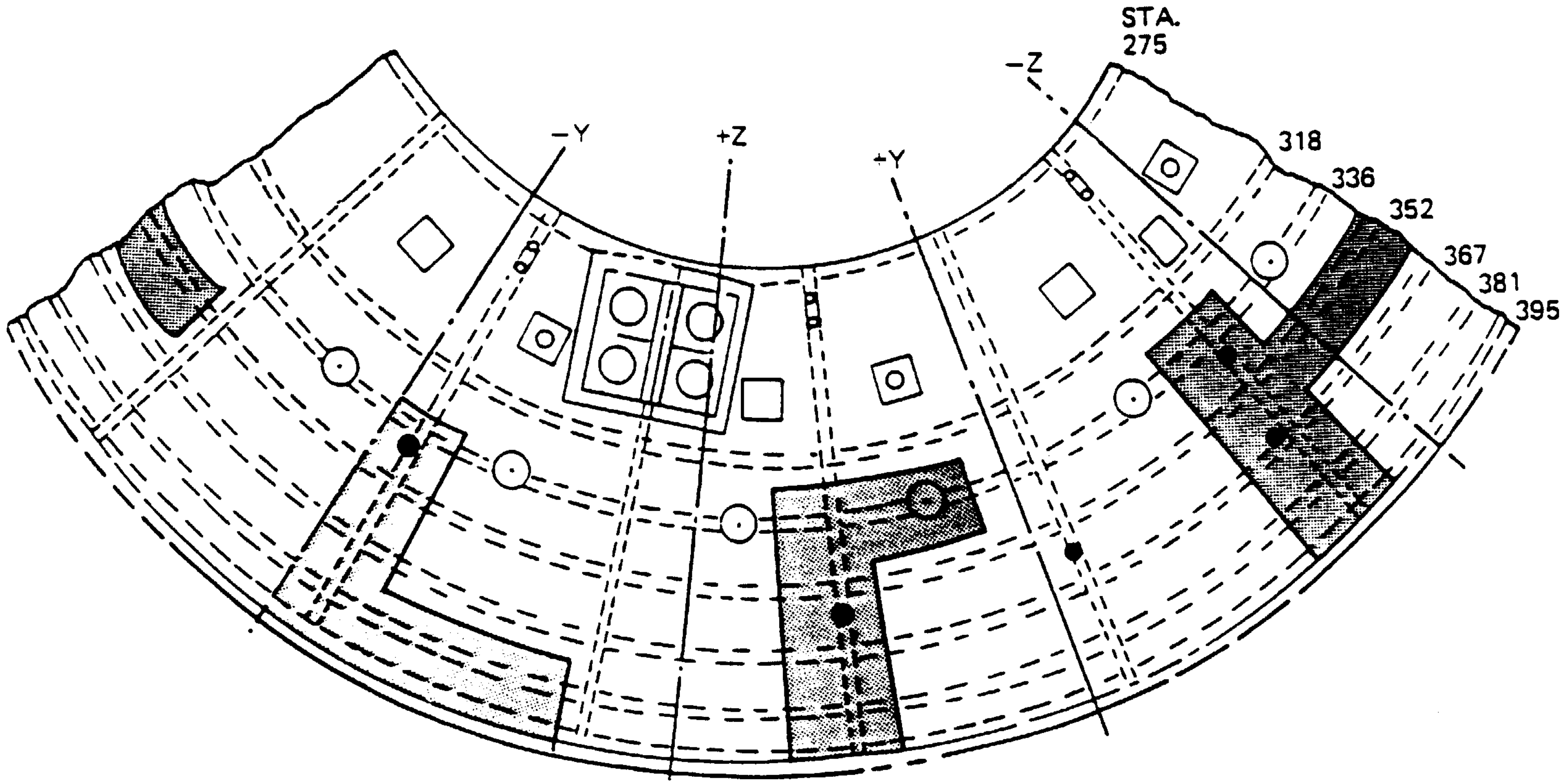
The Field Joint Protection System (FJPS) closeouts were generally in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. A 5"x1.5" area of TPS on the forward side of the upper strut fairing at the separation plane was missing but the substrate was not charred. The loss of TPS in this area may have occurred after strut separation. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The new RTV 1422 closeout was intact. All three aft booster stiffener rings sustained water impact damage. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring had delaminated. Ten K5NA protective domes were lost from bolt heads on the aft side of the phenolic kick ring prior to water impact (sooted substrate). The aft skirt acreage TPS was generally in good condition (Figure 13).

All Debris Containment System (DCS) plungers were seated properly with the exception of HDP #4, which was obstructed by frangible nut halves. This was the seventh flight utilizing the optimized link. None of the EPON shim material was lost during ascent.

Figure 11. **RIGHT SRB FRUSTUM**



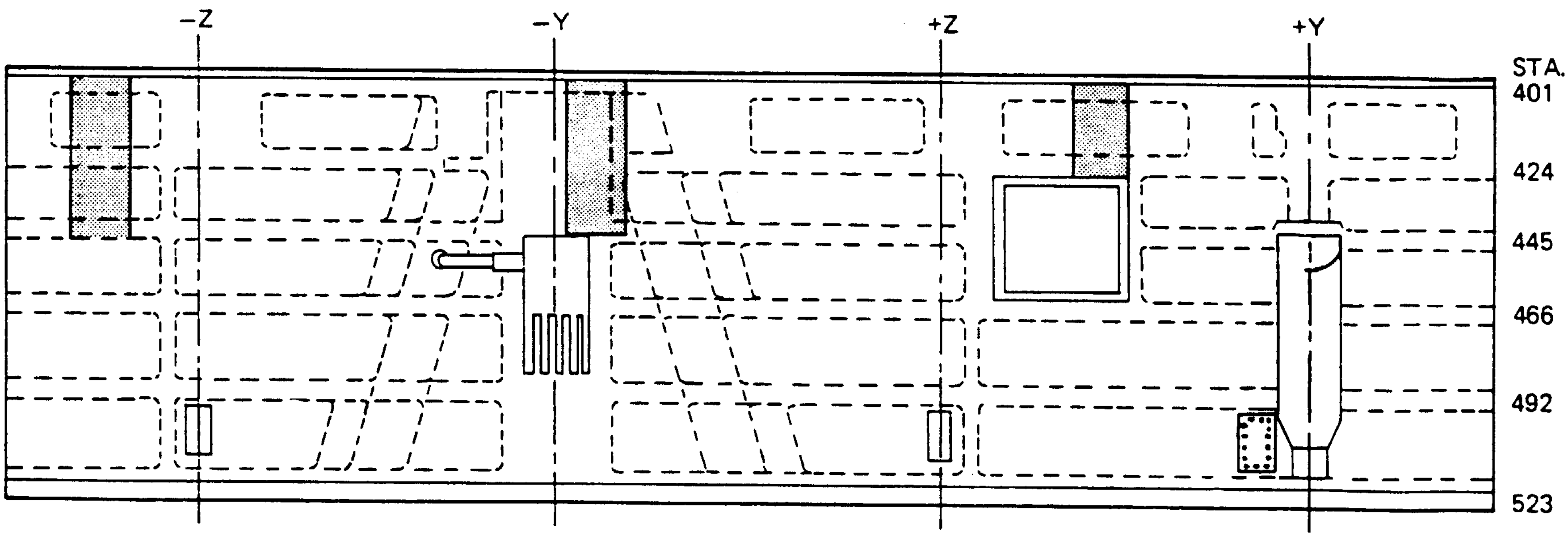
MISSING TPS
NONE

DEBONDS
● 5

MINOR BLISTERING OF HYPALON PAINT OCCURRED IN LOCALIZED AREAS ALONG 395 RING

'-326

Figure 12. **RIGHT SRB FWD SKIRT**



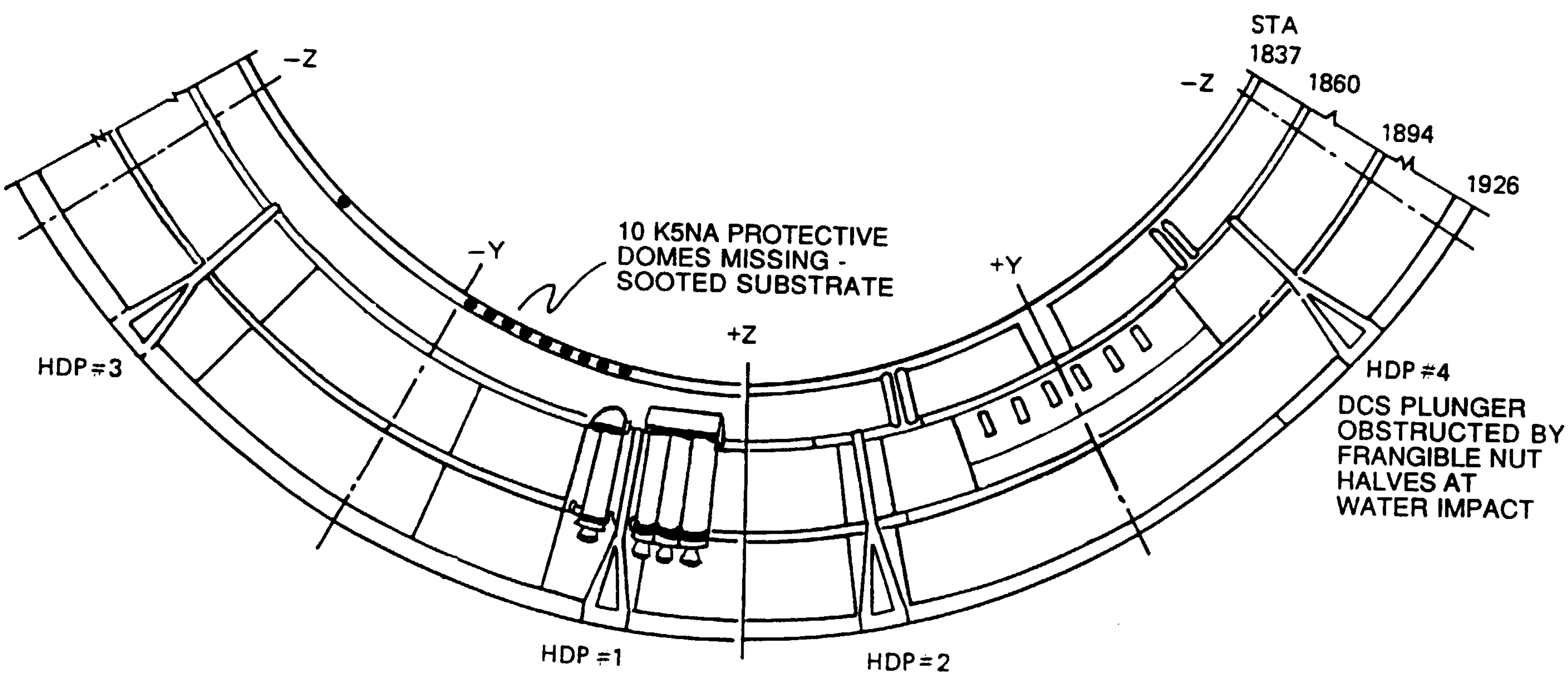
TPS MISSING
NONE

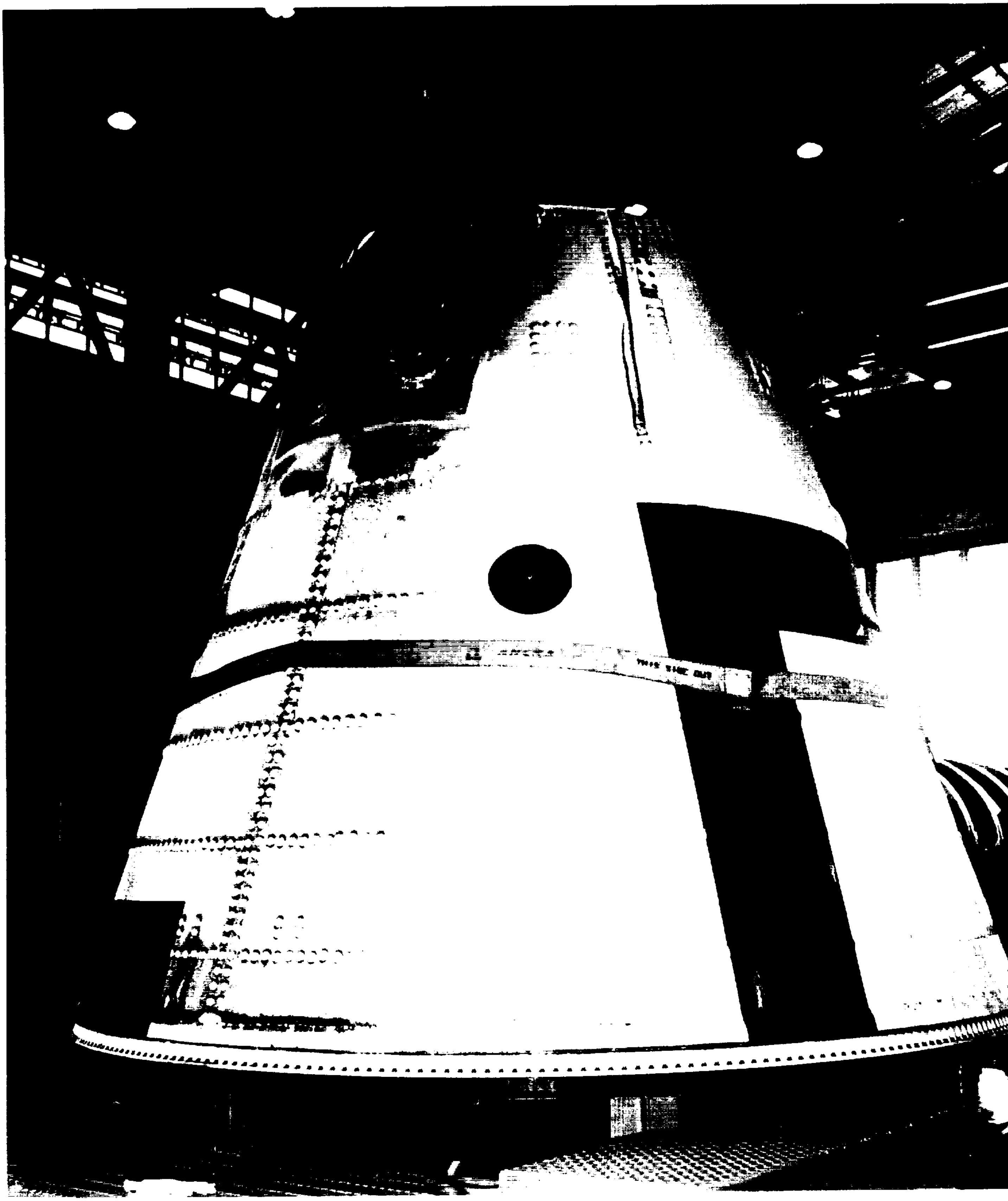
DEBONDS
NONE

MINOR BLISTERING OF HYPALON
PAINT ON SYSTEMS TUNNEL COVER

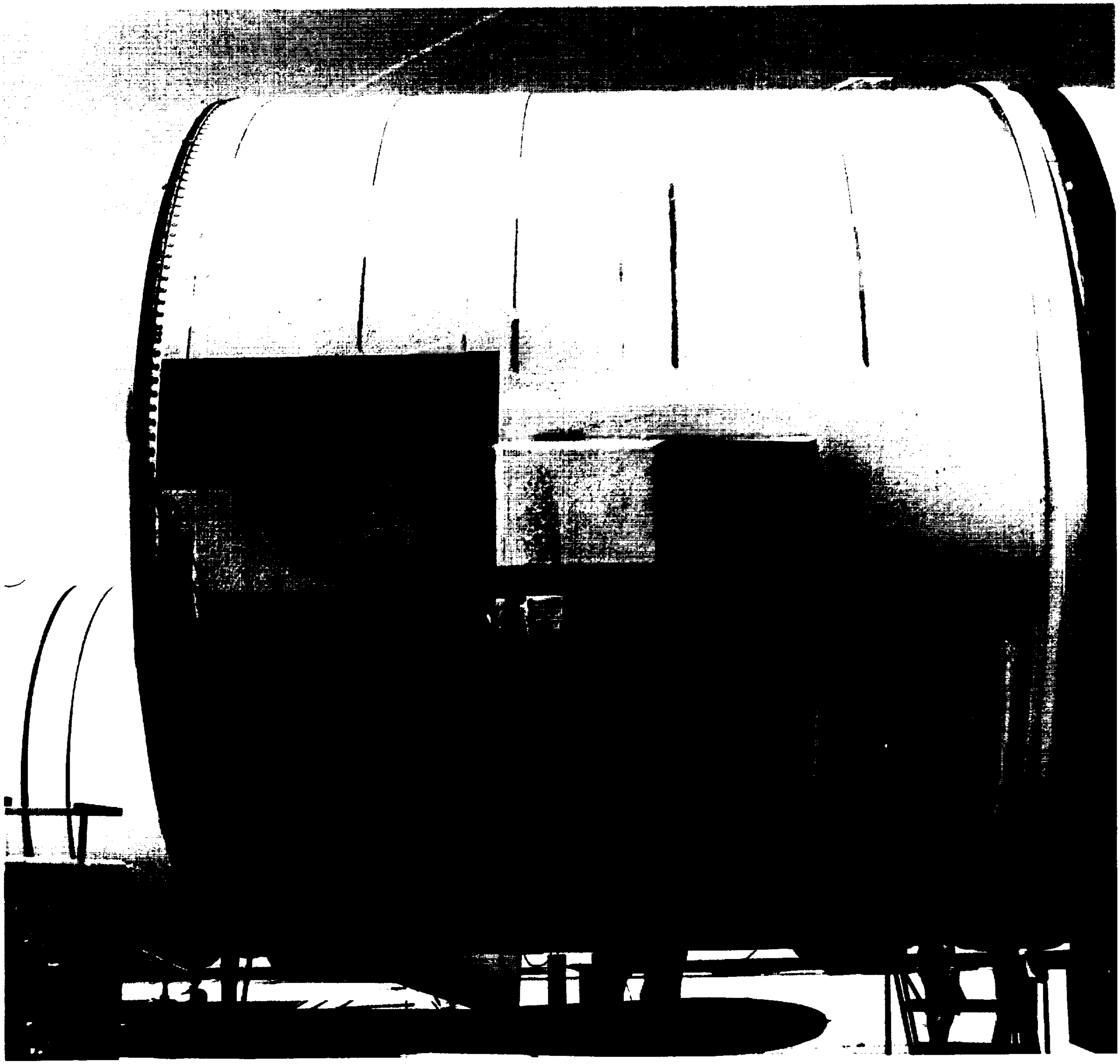
EGG/V 326A

Figure 13. **RIGHT SRB AFT SKIRT EXTERIOR TPS**





The RH frustum was missing no TPS but had 5 MSA-2 debonds over fasteners. Minor blistering of the Hypalon paint had occurred along the 395 ring. Two (right side) aero heat shield cover attach rings had been bent at the hinge by riser entanglement.



The RH forward skirt exhibited no debonds or missing TPS. Minor blistering of the Hypalon paint occurred in localized areas. Both RSS antenna phenolic plates were intact.

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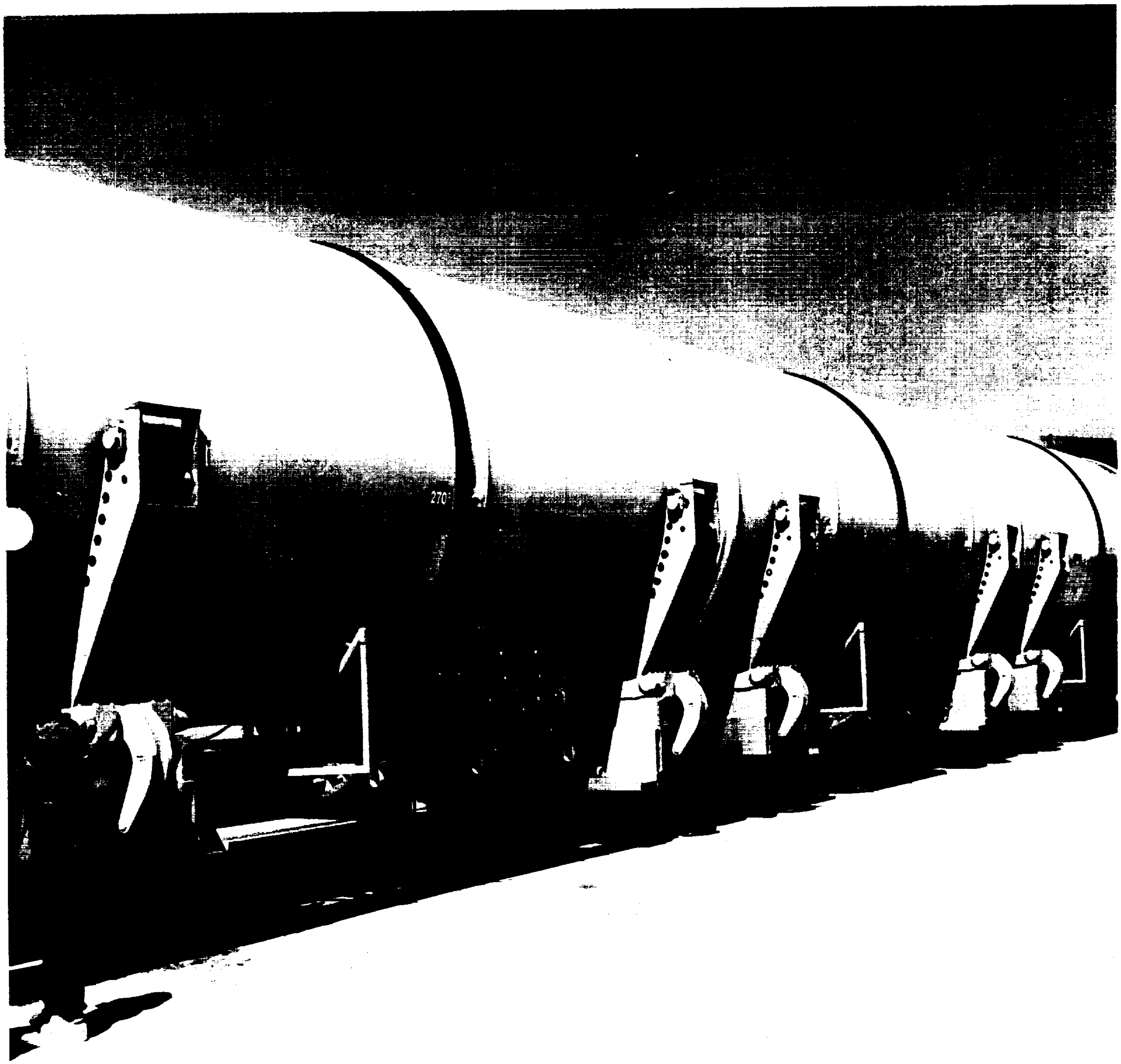
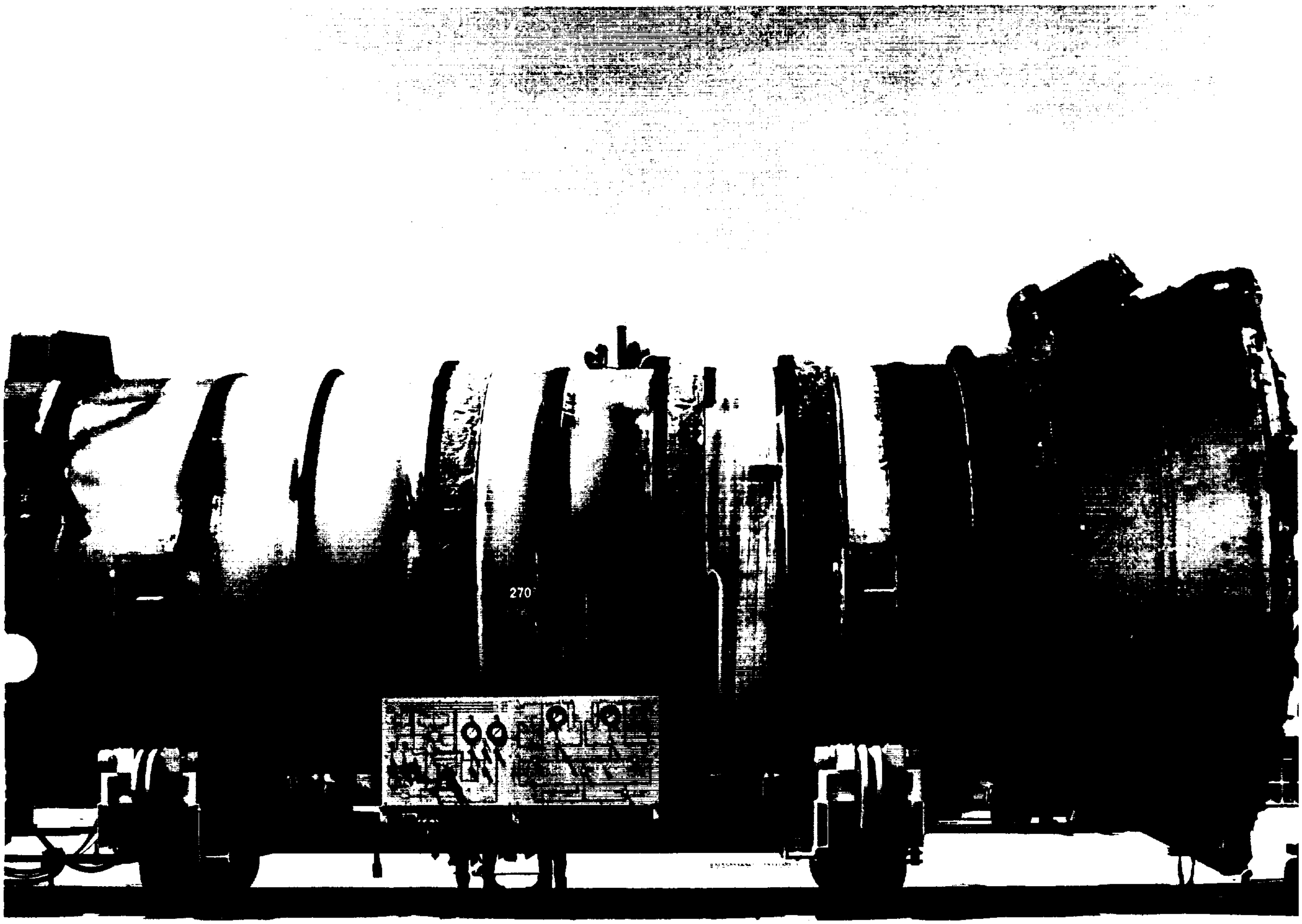


SRM segment cases, Field Joint Protection System (FJPS), and GEI cork run closeouts were in good condition.



Post flight condition of the RH aft booster. The aft skirt acreage TPS was sooted but in good condition. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. All three aft booster stiffener rings sustained water impact damage.

ORIGINAL PAGE
COLOR PHOTOGRAPH

A 5"x1.5" area of TPS on the forward side of the upper strut fairing at the separation plane was missing but the substrate was not charred. The loss of TPS may have occurred during strut separation.

8.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 9 MSA-2 debonds over fasteners. There was minor localized blistering of the Hypalon paint (Figure 14). The BSM aero heatshield covers were locked in the fully opened position.

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact though the material on the +Z antenna plate had delaminated (Figure 15). The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred near the ET/SRB attach point and on the systems tunnel cover.

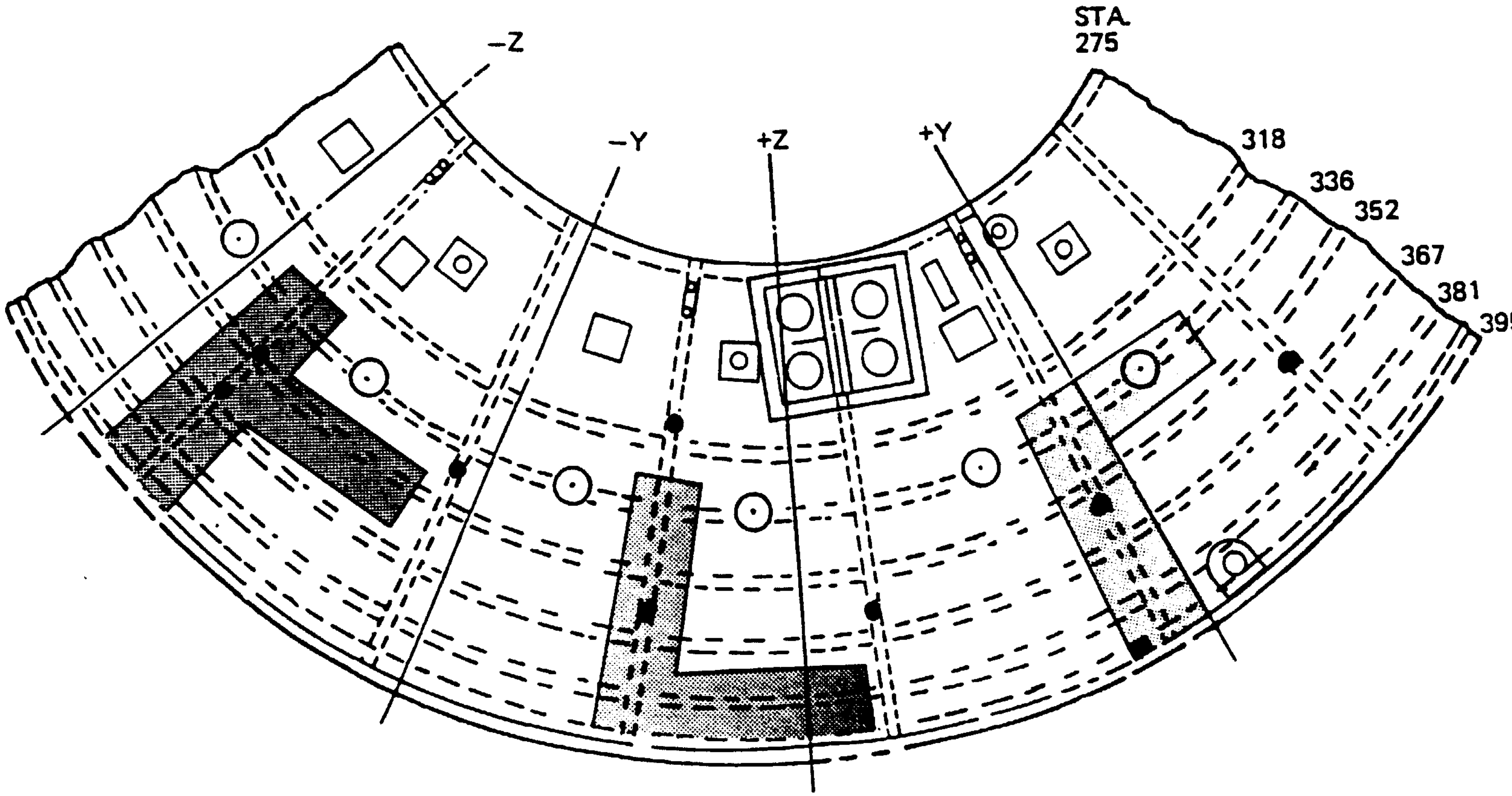
The Field Joint Protection System (FJPS) closeouts were in good condition. Minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. A 4.5"x3" area of TPS on the forward side of the upper strut fairing at the separation plane was missing and the substrate showed signs of heating. The loss of TPS in this area may have occurred during ascent or descent, but was not visible in the umbilical film at the time of strut separation. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The new RTV 1422 closeout was intact. All three aft booster stiffener rings sustained water impact damage. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Two K5NA protective domes were missing from bolt heads on the aft side of the phenolic kick ring prior to water impact (charred substrate). K5NA was missing from all aft BSM nozzles (Figure 16). The aft skirt acreage TPS was in good condition.

All four Debris Containment System (DCS) plungers were properly seated. This was the seventh flight utilizing the optimized link. None of the EPON shim material was lost prior to water impact.

Figure 14. **LEFT SRB FRUSTUM**

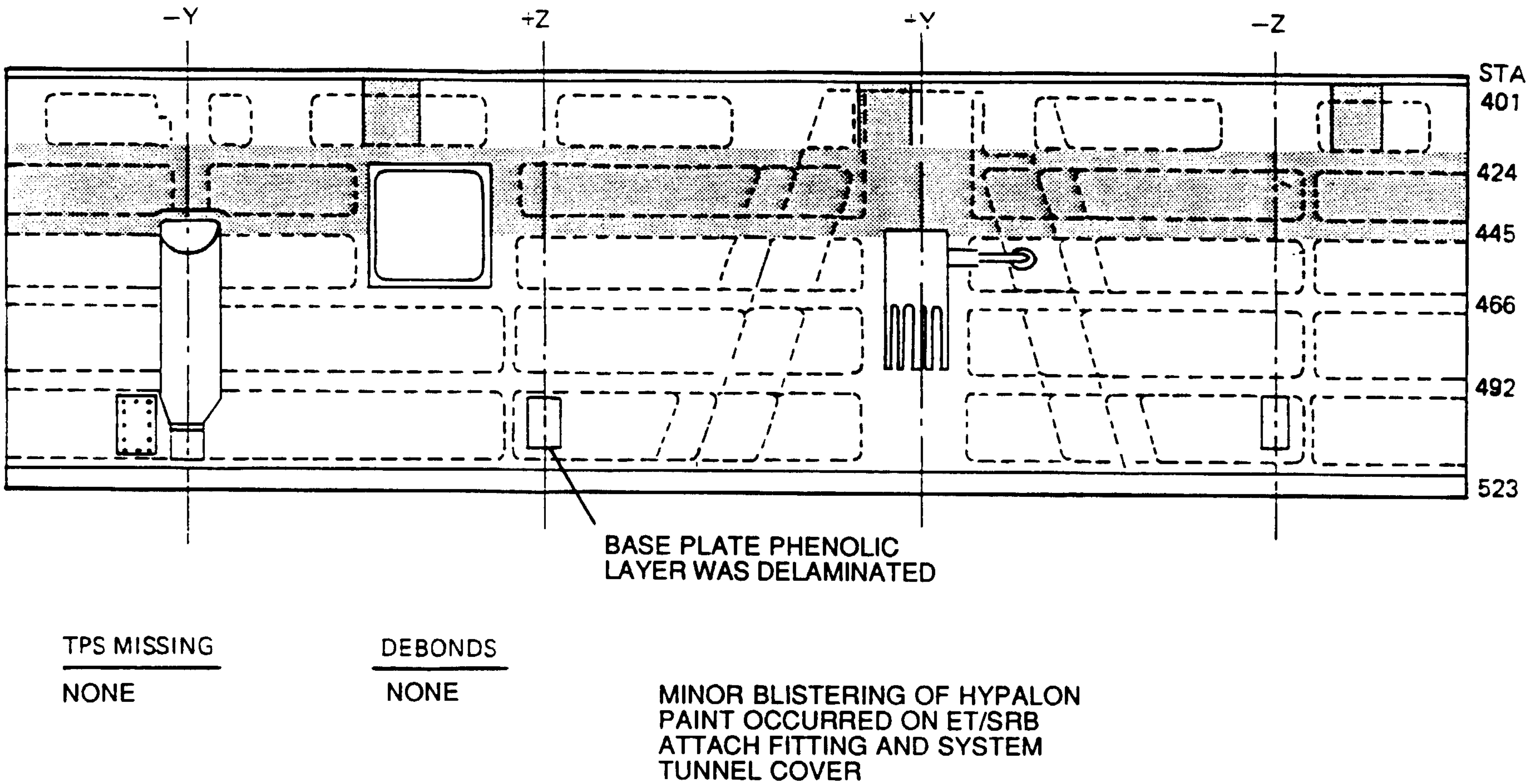


MISSING TPS
NONE

DEBONDS
● 9

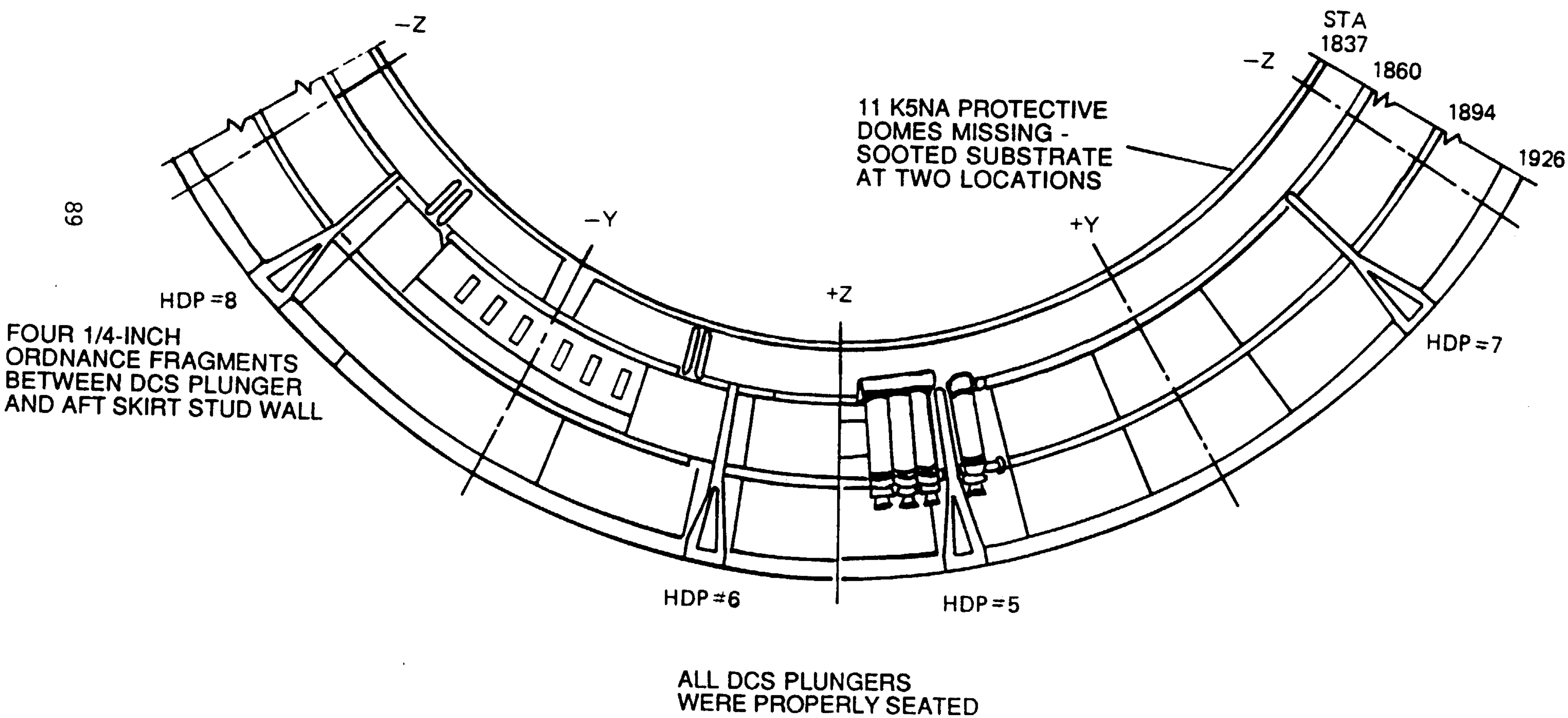
MINOR BLISTERING OF HYPALON PAINT OCCURRED IN LOCALIZED AREAS ALONG 395 RING

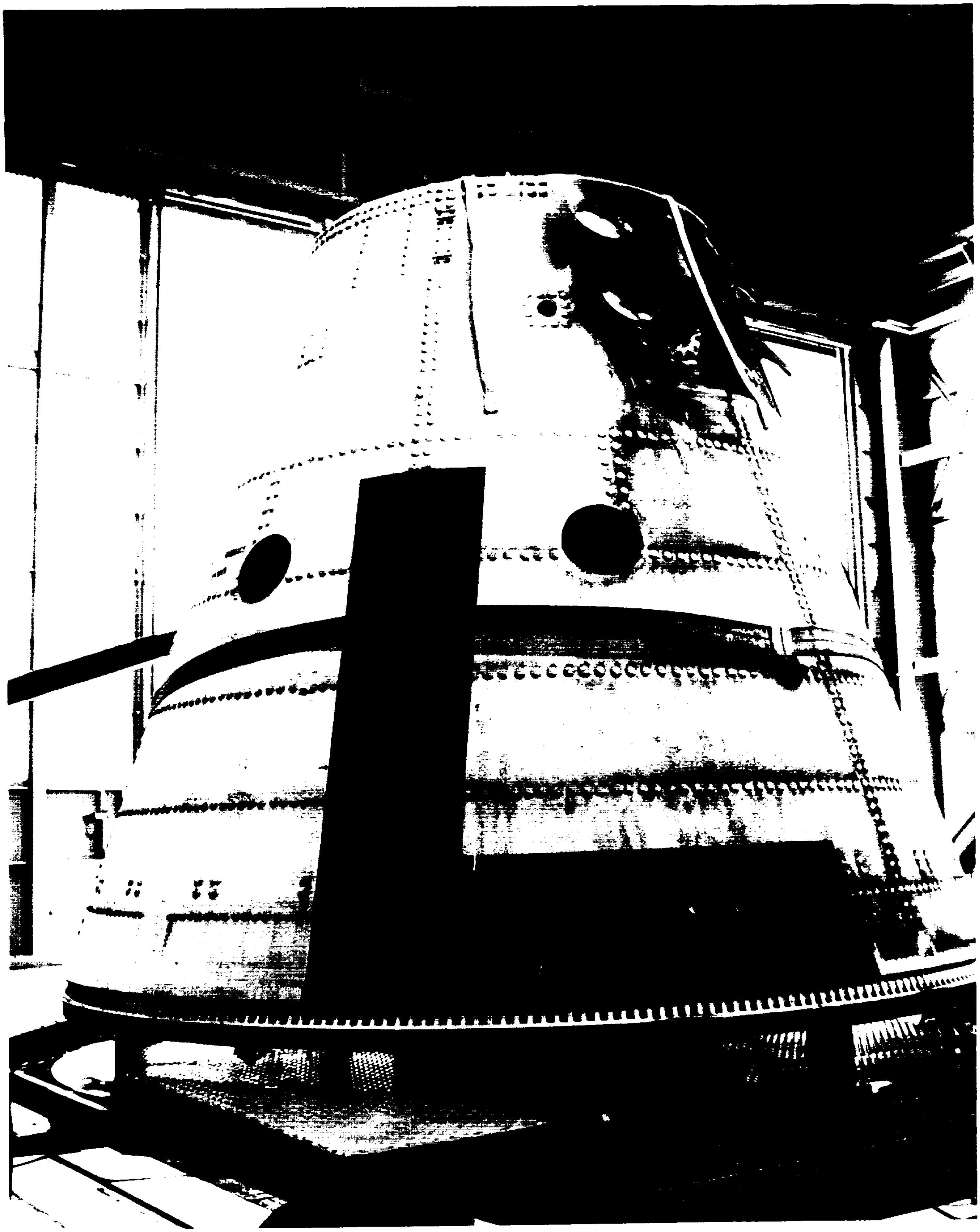
Figure 15. **LEFT SRB FWD SKIRT**



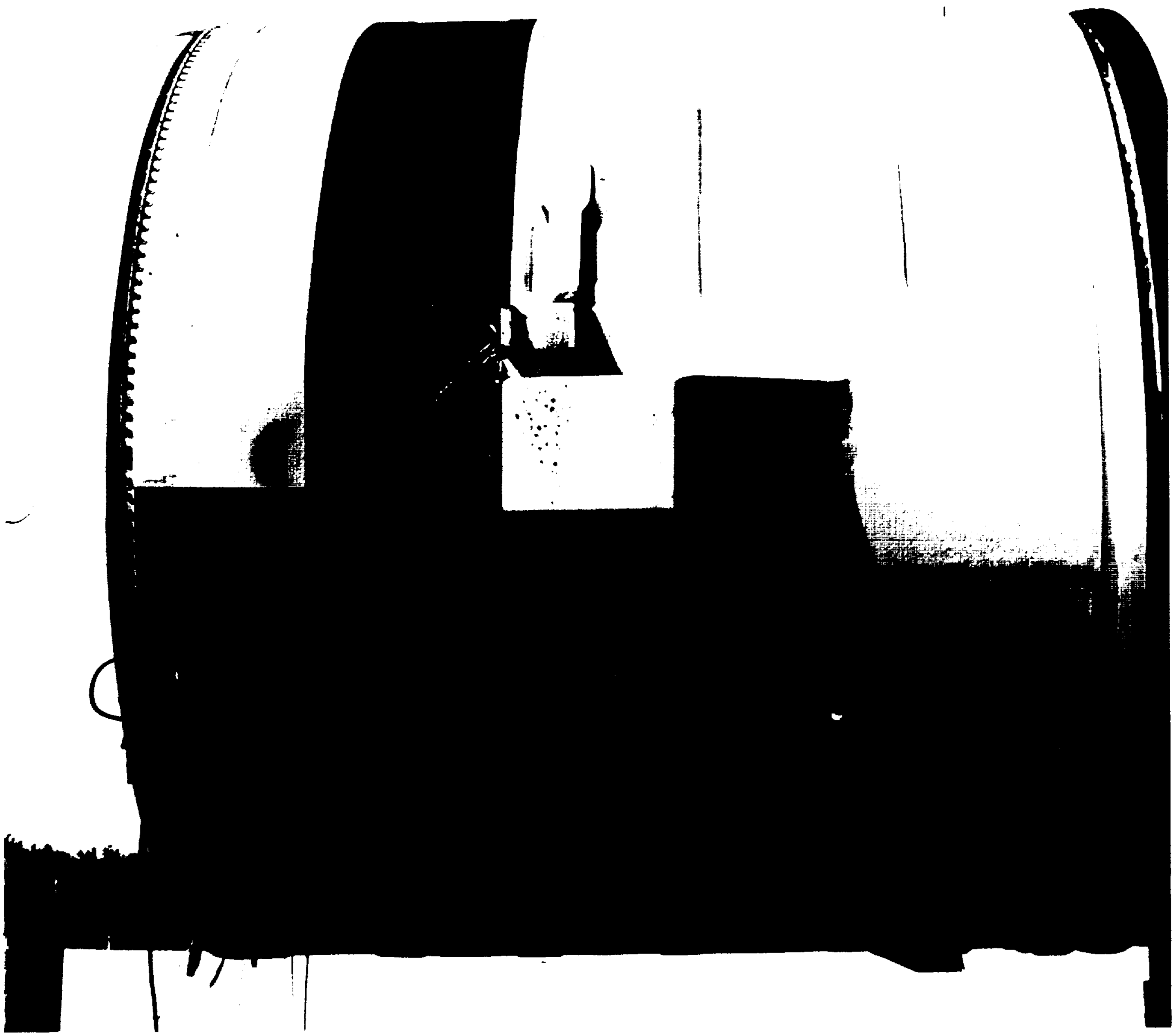
EGG/V-326D

Figure 16. **LEFT SRB AFT SKIRT EXTERIOR TPS**





The LH frustum was missing no TPS but had 9 MSA-2 debonds over fasteners. There was minor localized blistering of the Hypalon paint. The BSM aero heat shield covers were locked in the fully opened position.



The LH forward skirt exhibited no MSA-2 debonds or missing TPS. The phenolic plates on both RSS antennae were intact, though the material on the +Z plate had delaminated.

Post flight condition of the LH aft booster/aft skirt. The aft skirt acreage TPS was sooted but generally in good condition. The ET/SRB aft struts, IEA, and ETA ring appeared undamaged. All three aft booster stiffener rings sustained water impact damage.

A 4.5"x3" area of TPS on the forward side of the upper strut fairing at the separation plane was missing and the substrate showed signs of heating. The loss of TPS may have occurred during strut separation.

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COLOR PHOTOGRAPH

8.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 98 percent and individual holddown post retention percentages as listed:

HDP #	% of Nut without 2 large halves	% of Ordnance fragments	% Overall
1	91	95	93
2	99	92	99
3	99	99	99
4	99	55	83
5	99	95	99
6	99	100	99
7	100	99	99
8	99	97	99

STS-49 was the seventh flight to utilize the new "optimized" frangible links in the holddown post DCS's. The link was designed to increase the DCS plunger velocity and improve the seating alignment while leaving the stud ejection velocity the same. The design was intended to prevent ordnance debris from falling out of the DCS yet not increase the likelihood of a stud hang-up. According to NSTS-07700, the Debris Containment System should retain a minimum of 90 percent of the ordnance debris. Overall percentages of retention for the five previous flights utilizing the "optimized" link are:

HDP #	BI-044 STS-40	BI-045 STS-43	BI-046 STS-48	BI-047 STS-44	BI-048 STS-42	BI049 STS45
1	99%	98%	99%	99%	99	99
2	99%	**31%**	**88%**	99%	98	99
3	**38%**	99%	99%	99%	99	99
4	99%	99%	99%	99%	99	97
5	**23%**	99%	**58%**	99%	99	99
6	99%	99%	99%	99%	99	99
7	**62%**	99%	99%	99%	99	**8**
8	99%	99%	99%	99%	99	99
TOTAL	77%	90%	92%	99%	99%	87%

SRB Post Launch Anomalies are listed in Section 11.

9.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-105 (Endeavour) was conducted on May 16-17, 1992, at Ames-Dryden (EAFB) on runway 22 and in the Mate/Demate Device (MDD). This inspection was performed to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 114 hits, of which 11 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to engine vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 31 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42 which had damage from known debris sources), indicates that the total number of hits is slightly less than average and the number of hits one inch or larger is much less than average. Figures 17-20 show the TPS debris damage assessment for STS-49.

The Orbiter lower surface sustained a total of 55 hits, of which 6 had a major dimension of one inch or greater. The distribution of hits on the lower surface does not point to a single source of ascent debris, but indicates a shedding of ice and Thermal Protection System (TPS) debris from random sources.

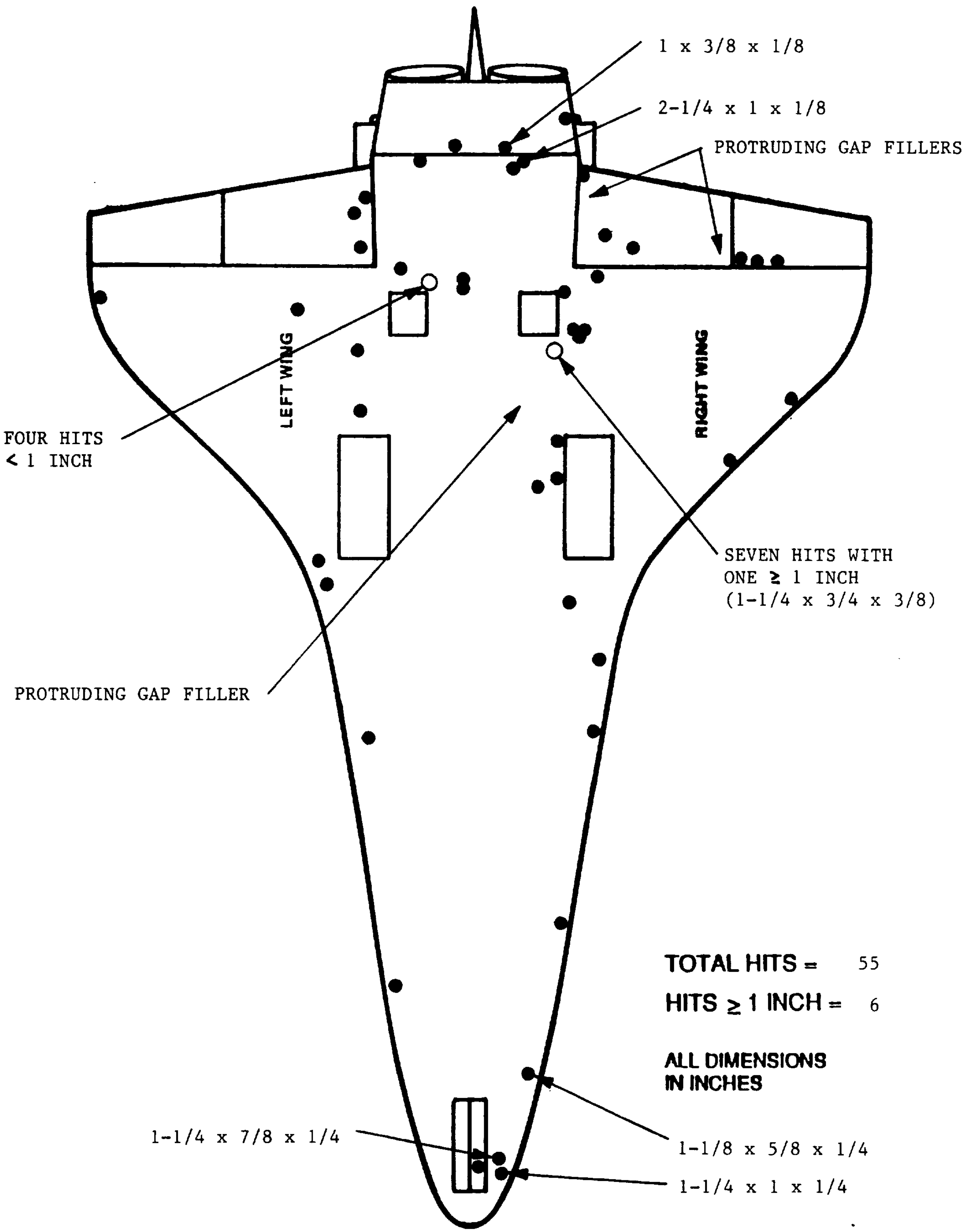
The most significant hit observed measured 9-5/8 x 2-5/8 x 1/4 inches and was located on the right side of the vehicle just aft of the nosecap RCC. The size and depth of this damage site is indicative of an impact by a low density material such as External Tank (ET) TPS foam.

The following table breaks down the STS-49 Orbiter debris damage by area:

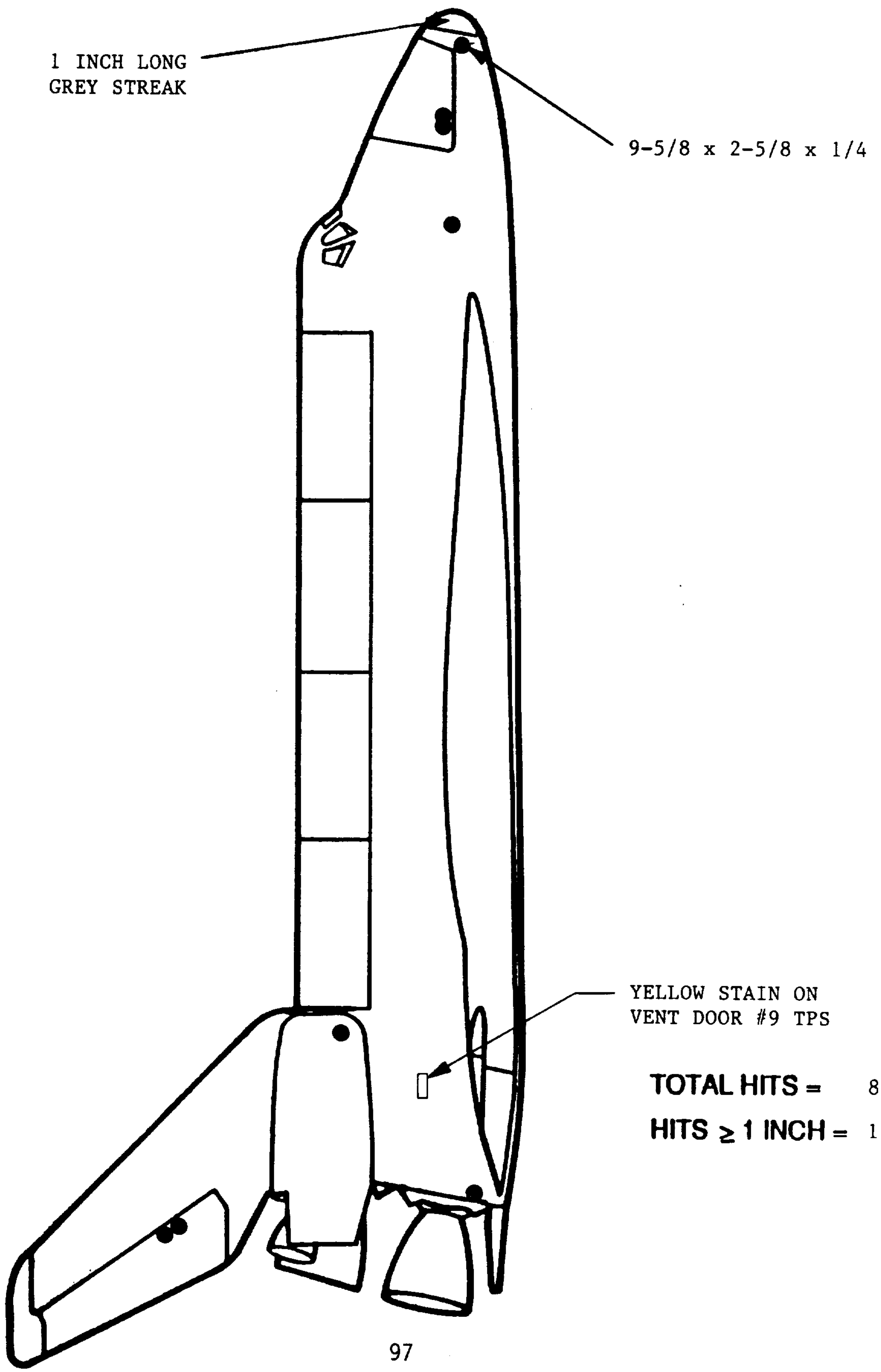
	HITS > 1"	TOTAL HITS
Lower surface	6	55
Upper surface	1	39
Right side	1	7
Left side	2	6
Right OMS Pod	1	4
Left OMS Pod	0	3
TOTALS	11	114

No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires were considered to be in good condition for a concrete runway landing.

STS-49
Figure 17.
DEBRIS DAMAGE LOCATIONS

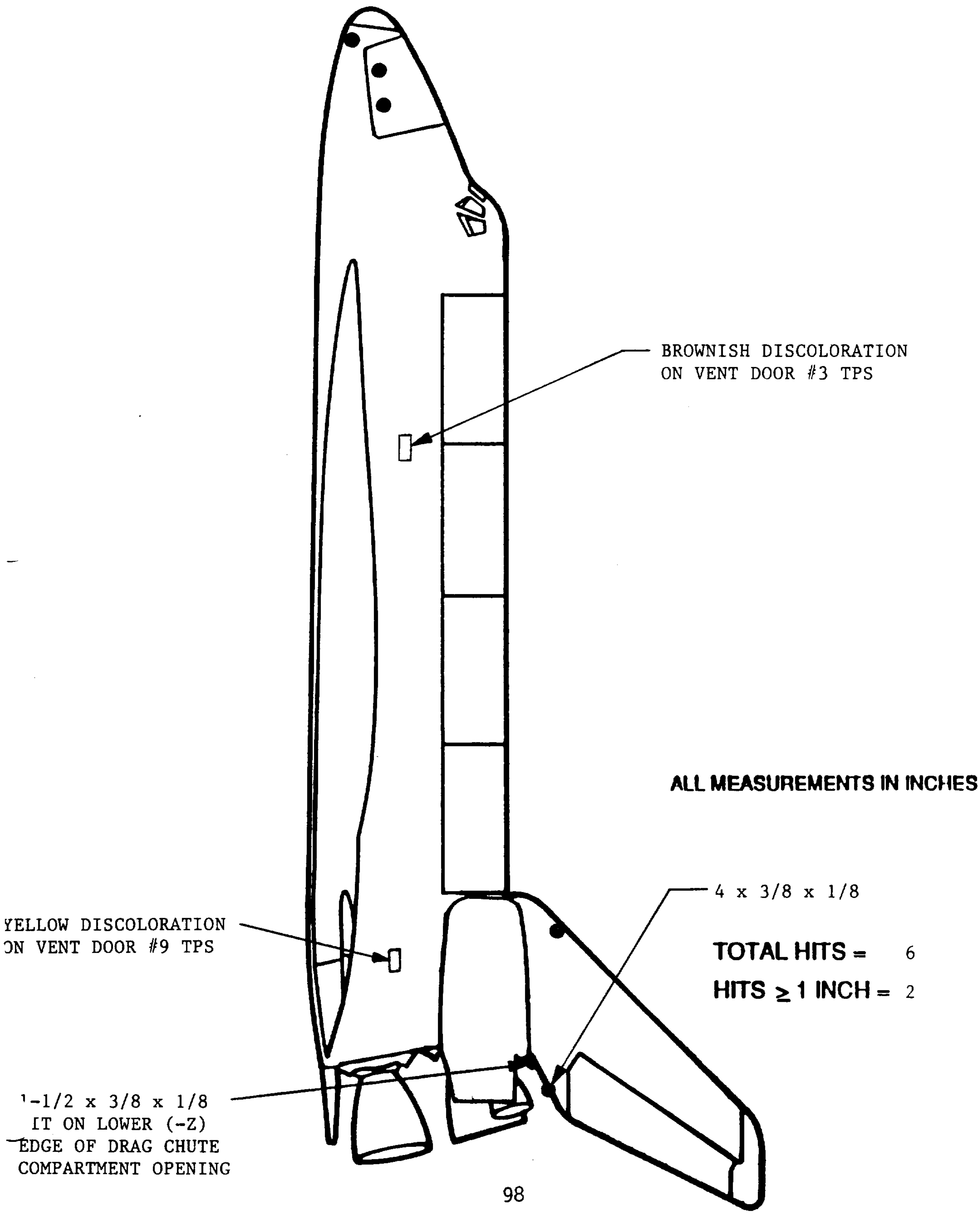


STS-49
Figure 18
DEBRIS DAMAGE LOCATIONS

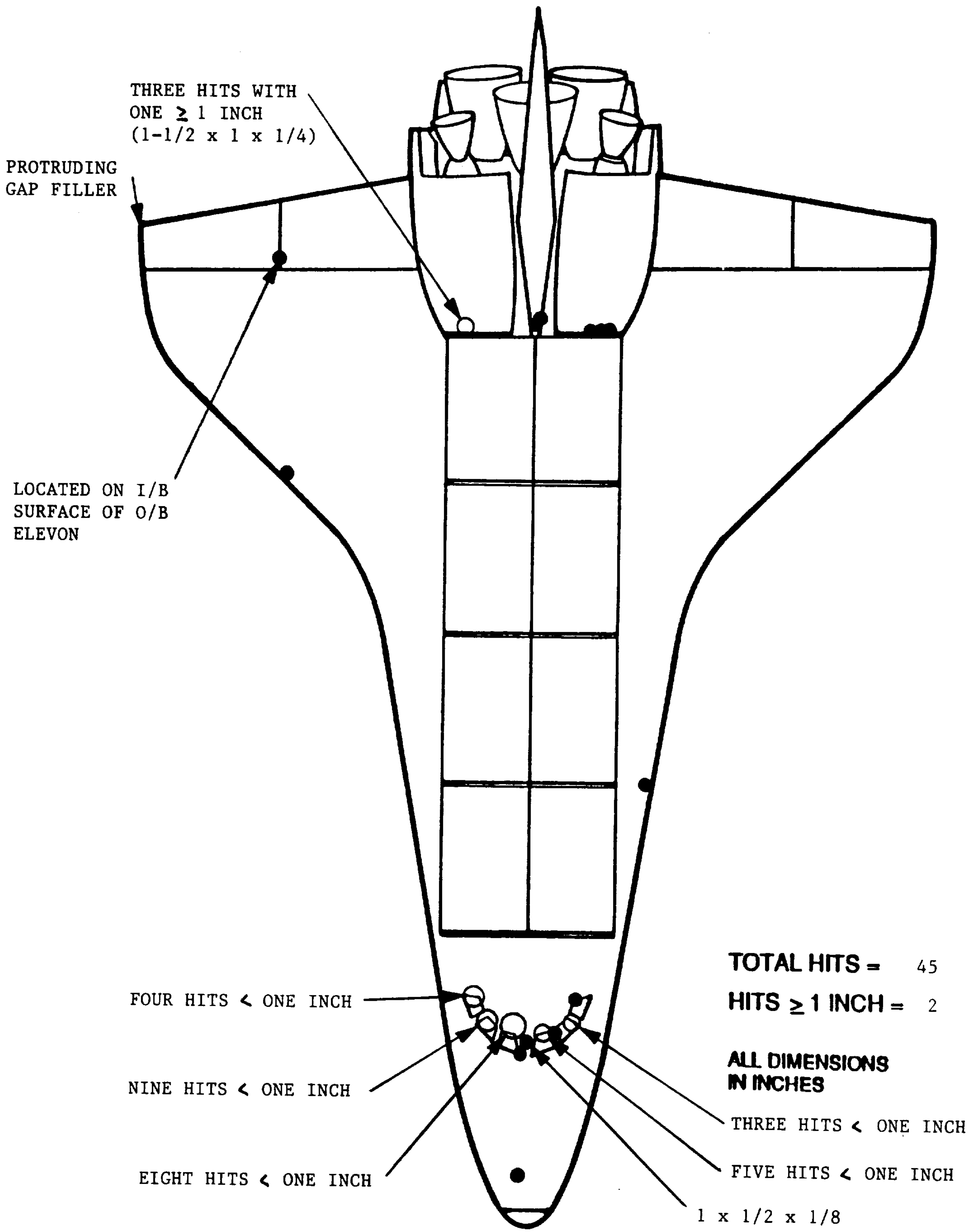


5/17/92

STS-49
Figure 19
DEBRIS DAMAGE LOCATIONS



STS-49
Figure 20
DEBRIS DAMAGE LOCATIONS



The following items were found on the runway underneath the RH ET/Orbiter umbilical door: a 3/4-inch long segment of a Jo-bolt, a 1/2-inch OD by 1/4-inch ID by 1/16-inch thick spacer (washer), and a 1/2-inch long 10-32 Torx head screw (Part No. MD 112-1003-04). A 7/16-inch long 10-32 Torx head screw (Part No. MD 112-1003-04 SPS) was found on the runway underneath the LH ET/Orbiter umbilical door. Problem Report LAF-5-02-0038 was written to document the items found beneath the RH door and PR LAF-5-02-0037 was written to document the one item found under the LH door.

All ET/Orbiter (EO) separation ordnance device plungers appeared to have functioned properly. However, the red spacer/shim in the bowl of EO-2 (LH side) was displaced forward approximately 1/4 inch. The stop-bolts on the EO-1 separation assembly did not sustain any damage/bending.

Damage to the base heat shield tiles was much less than normal. There were no indications of tile damage in the center of the base heat shield resulting from the "oscillations" observed in launch motion picture photography. Several tiles on the centerline of the body flap stub upper surface and adjacent tiles on the body flap upper surface were damaged. The cause of this damage is unknown and is under investigation by TPS engineering. The main engine Dome Mounted Heat Shield (DMHS) blankets were intact and showed no signs of fraying.

All Orbiter windows exhibited typical hazing. A few small streaks were present on windows #3 and #4. Laboratory analysis will be performed on samples taken from all windows. During the 8th flight day, an impact on window #1 was photographed by the crew. Post flight assessment showed a crater depth of 0.003897 inches, which is over six times the maximum depth of 0.0006 inches.

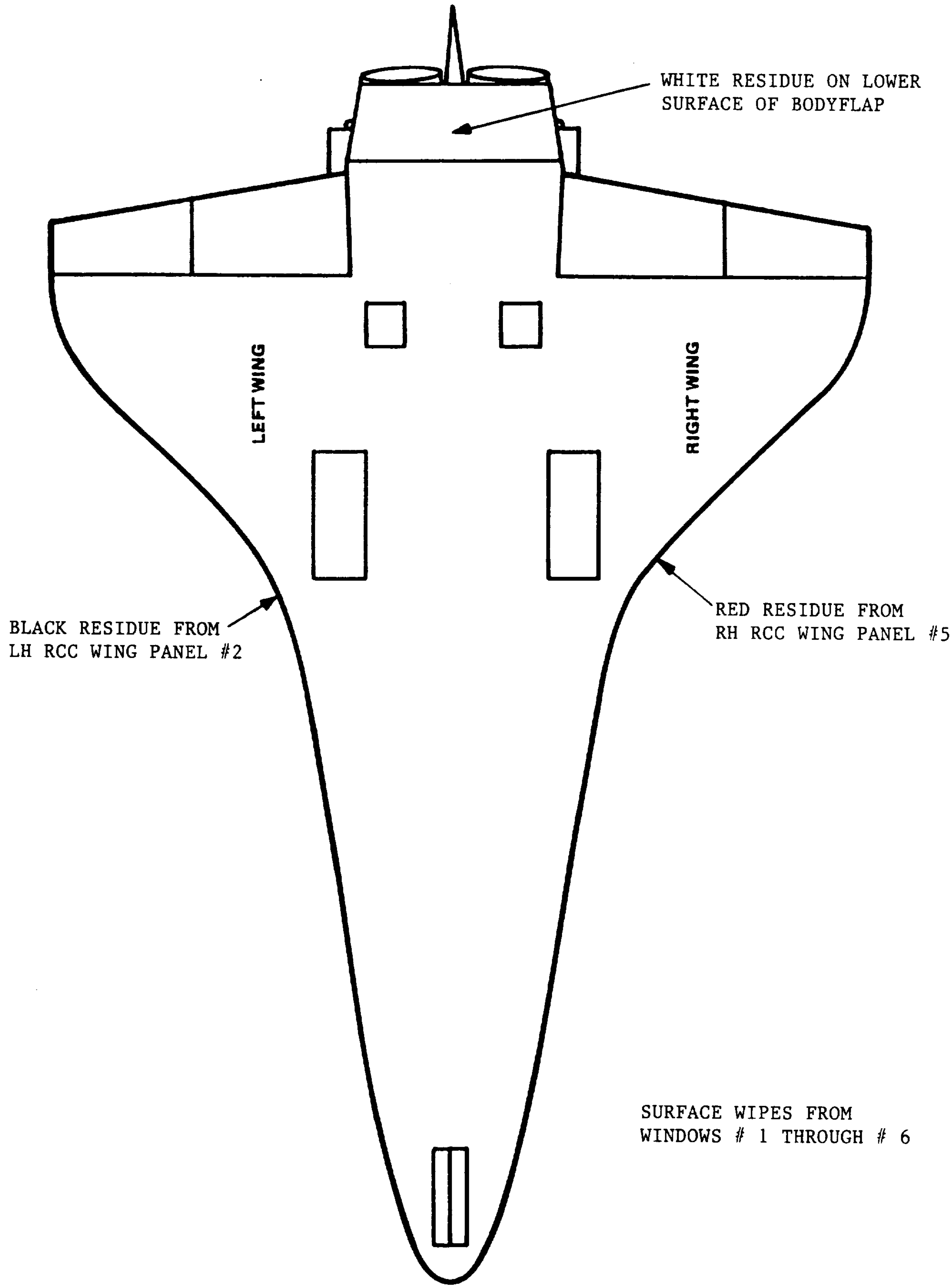
Samples were taken from other selected sites for laboratory analysis (reference Figure 21).

The TPS blankets covering both the RH and LH #9 vent doors exhibited a yellowish discoloration, which appeared similar, although not as pronounced, as that observed on the OV-103 RH vent door #7 after the STS-42 mission. Two PRs were written by TPS engineering to document this anomaly. LH vent door #3 exhibited a light brown discoloration, but was not documented on a PR since TPS engineering determined that this discoloration was caused by normal aero-heating.

A number of damage sites were noted on the perimeter tiles of the Orbiter windows (reference Figure 20). Most of the impact sites were only surface coating losses or were no more than 1/16th inch deep. This damage may have been caused by the RTV used to bond paper covers to the FRCS nozzles or by exhaust products from the SRB booster separation motors.

STS-49
Figure 21

CHEMICAL SAMPLE LOCATIONS



An infrared radiometer was used to measure the surface temperature of several areas of the Orbiter TPS after landing (per OMRSD V09AJ0.095). Ninety-seven minutes after wheel stop, the Orbiter nosecap RCC was 162 degrees F, the RH wing leading edge RCC panel #9 was 143 degrees F, and the RH wing leading edge RCC panel #17 was 140 degrees F (reference Figure 22). The wing RCC panel temperatures are approximately 55 degrees F above average. After an investigation of this phenomenon, JSC RCC sub-system engineering concluded that the observed elevated temperatures were within expected limits and were caused by the combination of high ambient temperature, low wind speed, and the new "double type A" coating used on the OV-105 RCC panels.

Runway 15 was inspected by the Debris Team on May 15, 1992 and all potentially damaging debris was removed. Runway 22 was inspected and swept by Air Force personnel on the same day. Both runways were found to be in acceptable condition for landing.

A post-landing inspection of runway 22 was performed immediately after landing. The only unanticipated flight hardware items found were two Tempilabels, which probably originated from the landing gear/wheel wells.

This flight marked the first use of the Orbiter drag chute. According to Deceleration System engineering, the drag chute functioned nominally. However, two tiles, one on the lower (-Z) edge of the drag chute opening and the other on the LH lower edge of the vertical stabilizer "stinger", were damaged by the drag chute deployment (reference Figure 24). All drag chute hardware was recovered and showed no signs of abnormal operation. The drag chute mortar cover was found approximately 5,650 feet from the Orbiter, 50 feet to the left of the runway centerline. The chute door was found approximately fifty feet closer to the Orbiter on the runway centerline. Four distinct door impact marks were observed to the left of the runway centerline. The sabot and attached pilot chute bag were another 10 feet closer to the Orbiter and 10 feet left of the centerline. The pilot chute was an additional 30 feet closer to the orbiter and 15 feet right of the centerline. The main chute was located approximately 750 feet from the Orbiter just to the right of the centerline.

In summary, the total number of Orbiter TPS debris hits was slightly less than average and the number of hits with a major dimension of one inch or greater was much less than average when compared to previous flights (reference Figures 23-25).

Orbiter Post Launch Anomalies are listed in Section 11.

Figure 22

STS- 49 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER

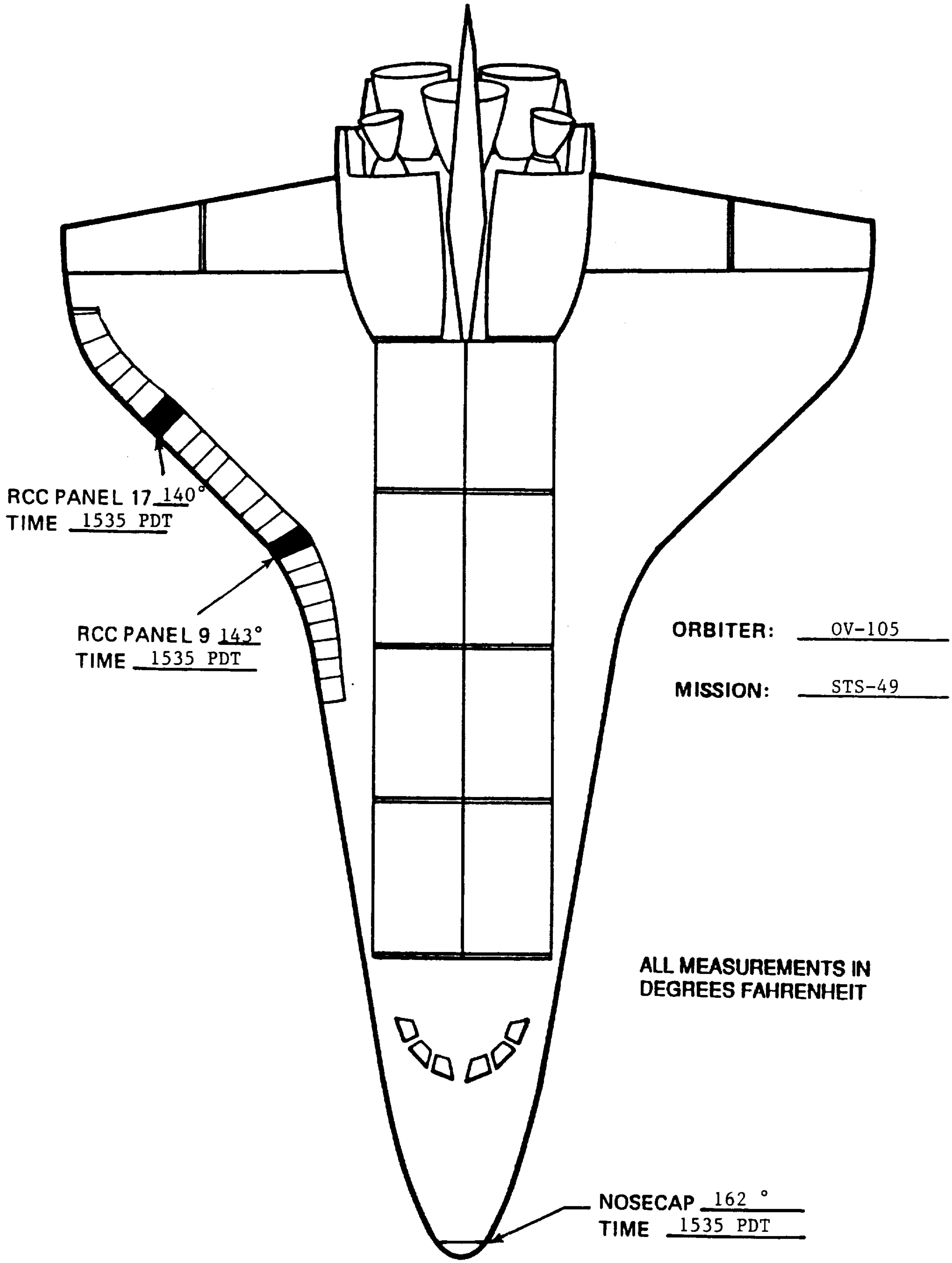
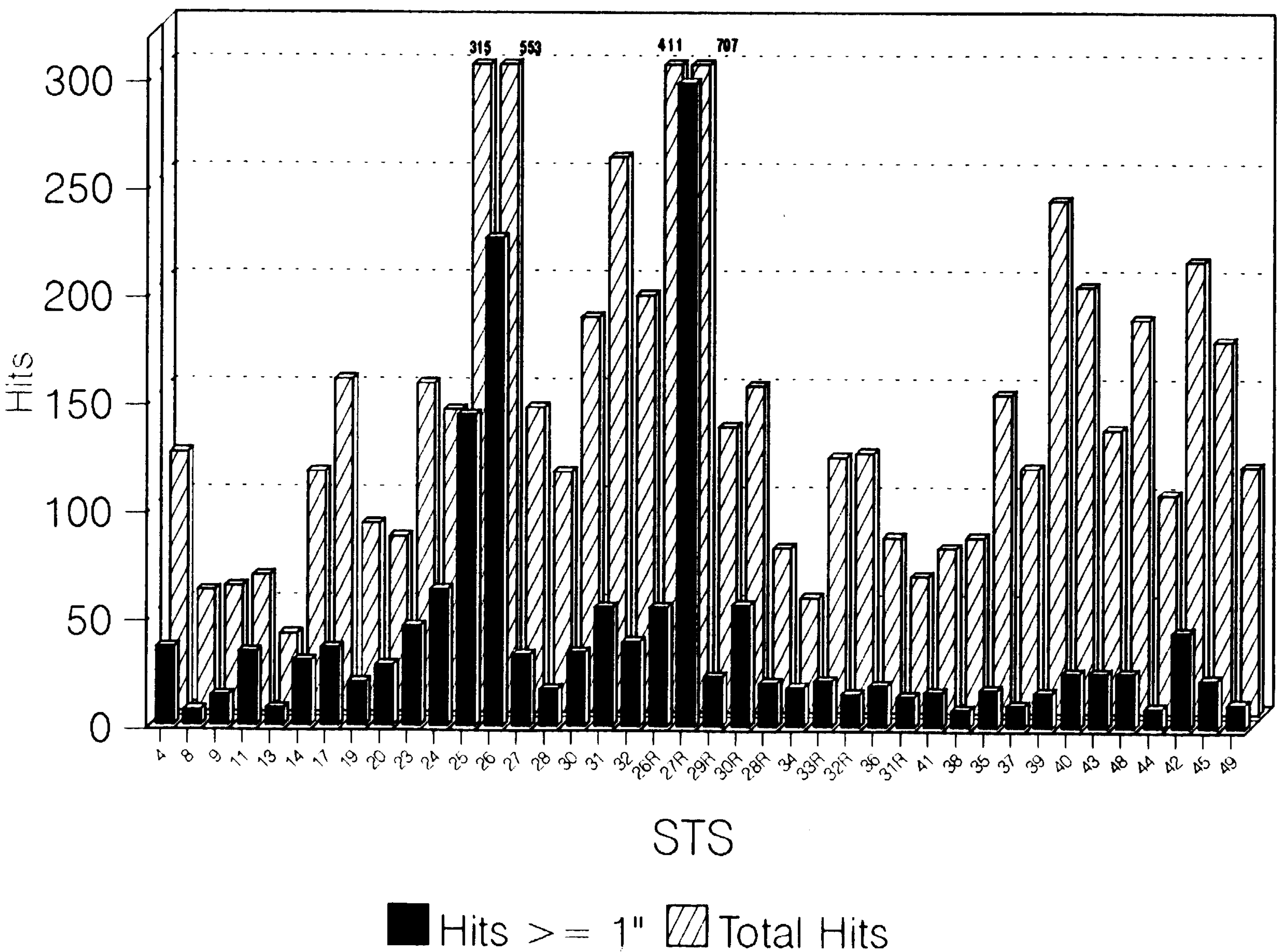


FIGURE 23. ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
AVERAGE	15.4	88.2	22.4	120.4
SIGMA	7.2	44.4	10.7	54.8
STS-49	6	55	11	114

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

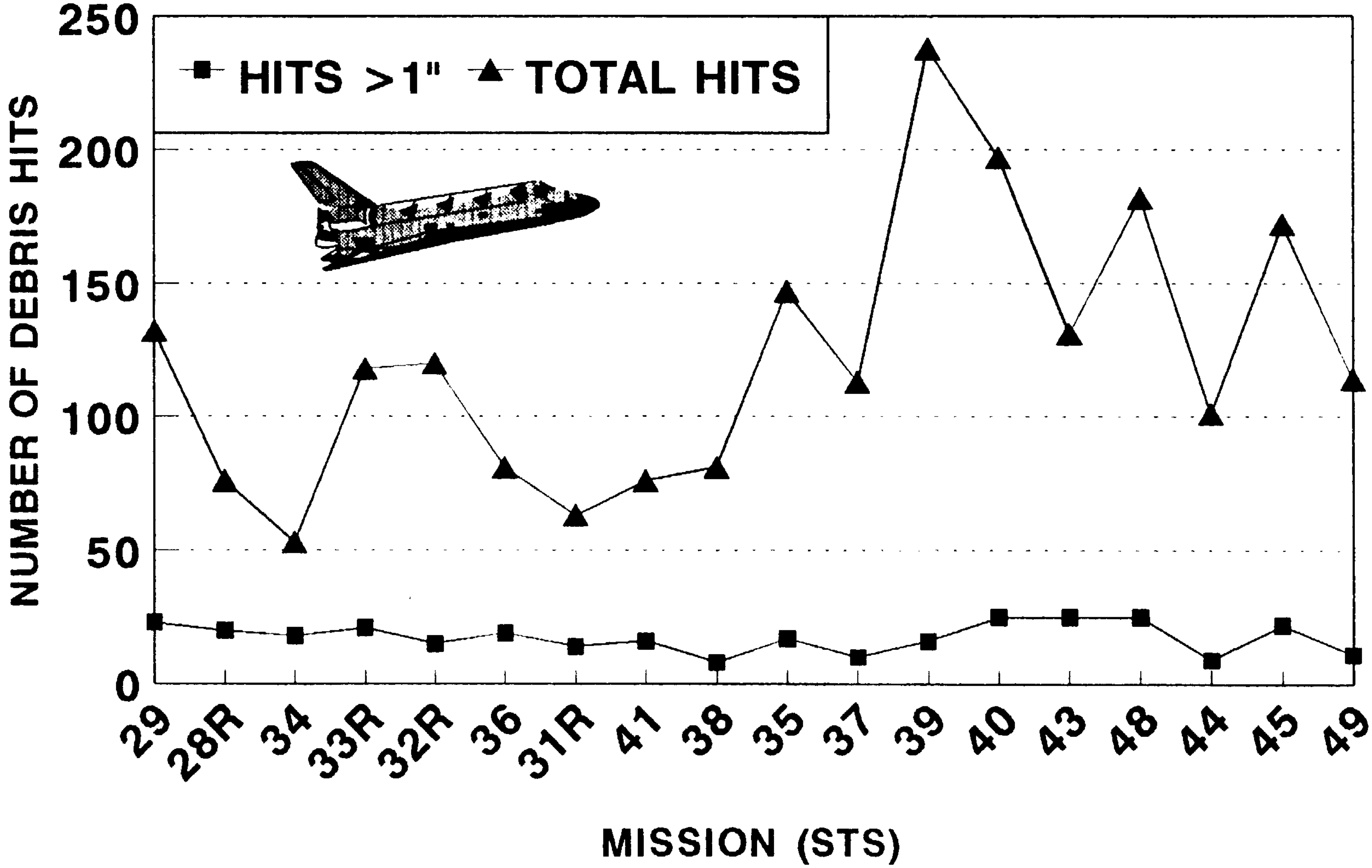
Figure 24. **COMPARISON TABLE**



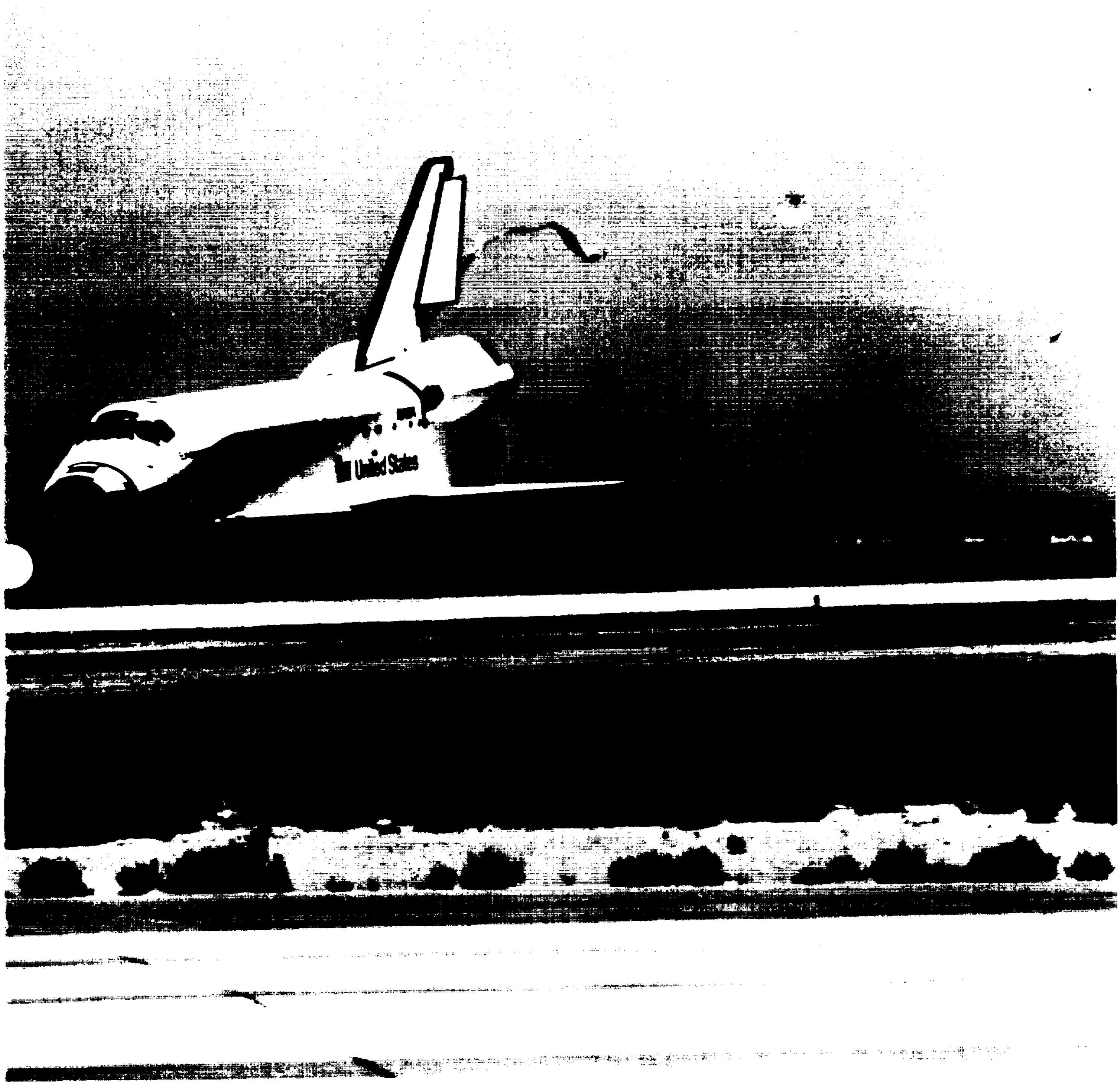
ORBITER TPS DEBRIS DAMAGE

STS-29 THROUGH STS-49

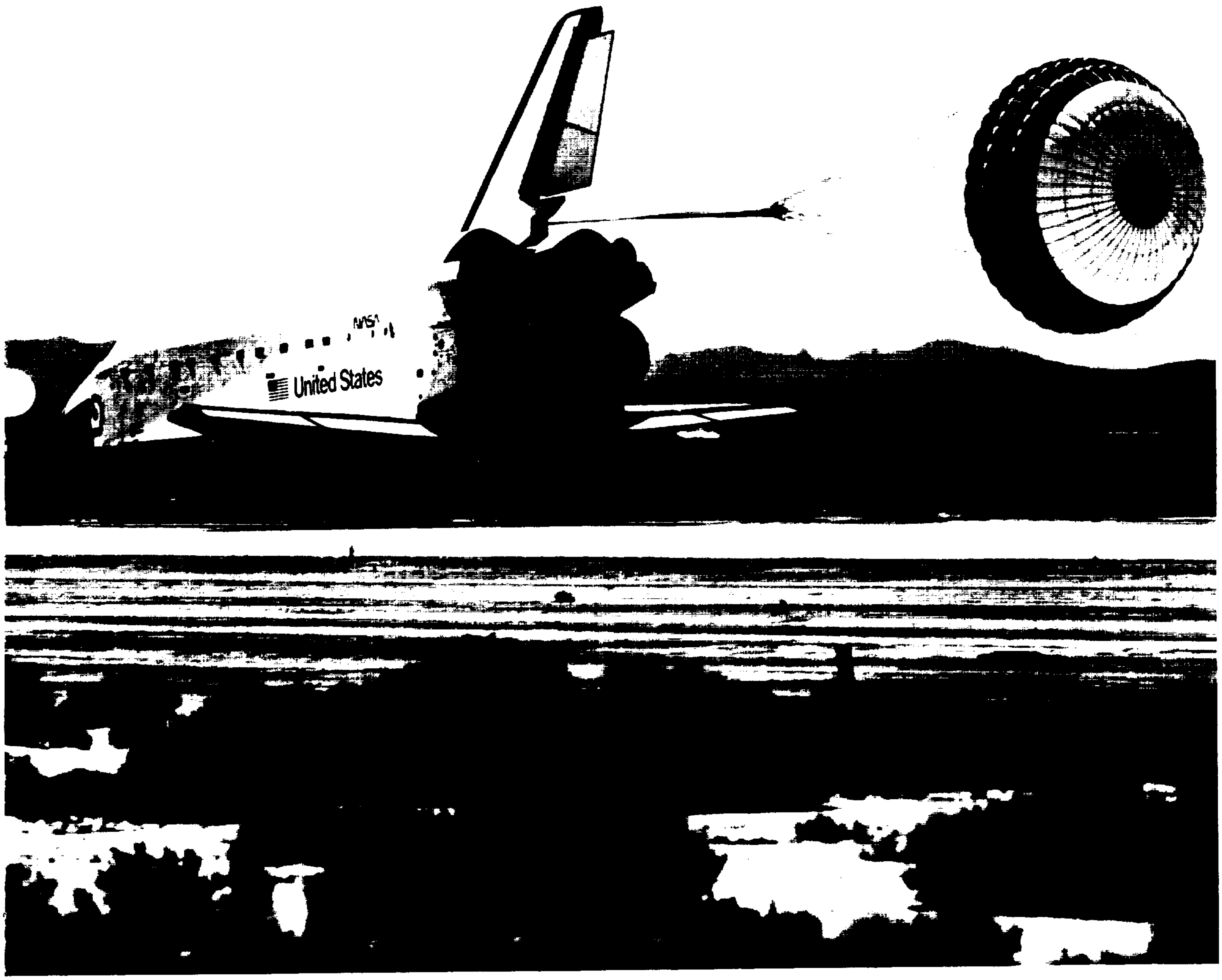
Figure 25



EXCLUDES MISSIONS STS-30R AND 42 WHICH EXPERIENCED SIGNIFICANT DAMAGE FROM KNOWN DEBRIS SOURCES



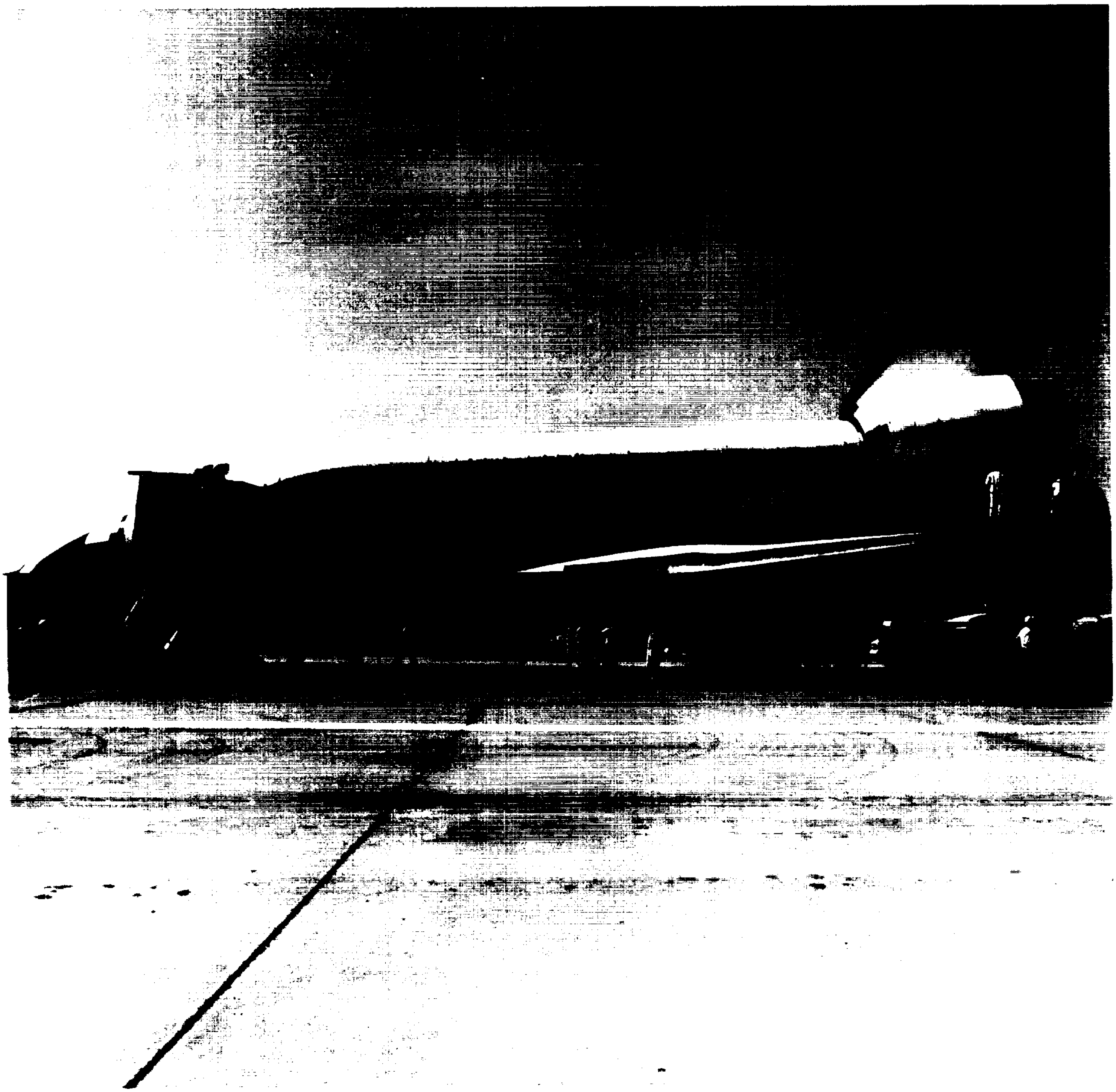
This flight marked the first use of the Orbiter drag chute, which functioned normally. The drag chute compartment door and the sabot/pilot chute bag are visible at the right side of the frame.



Deployment of the drag chute was nominal. The risers did not contact the SSME #1 nozzle or the rudder/speed brake.

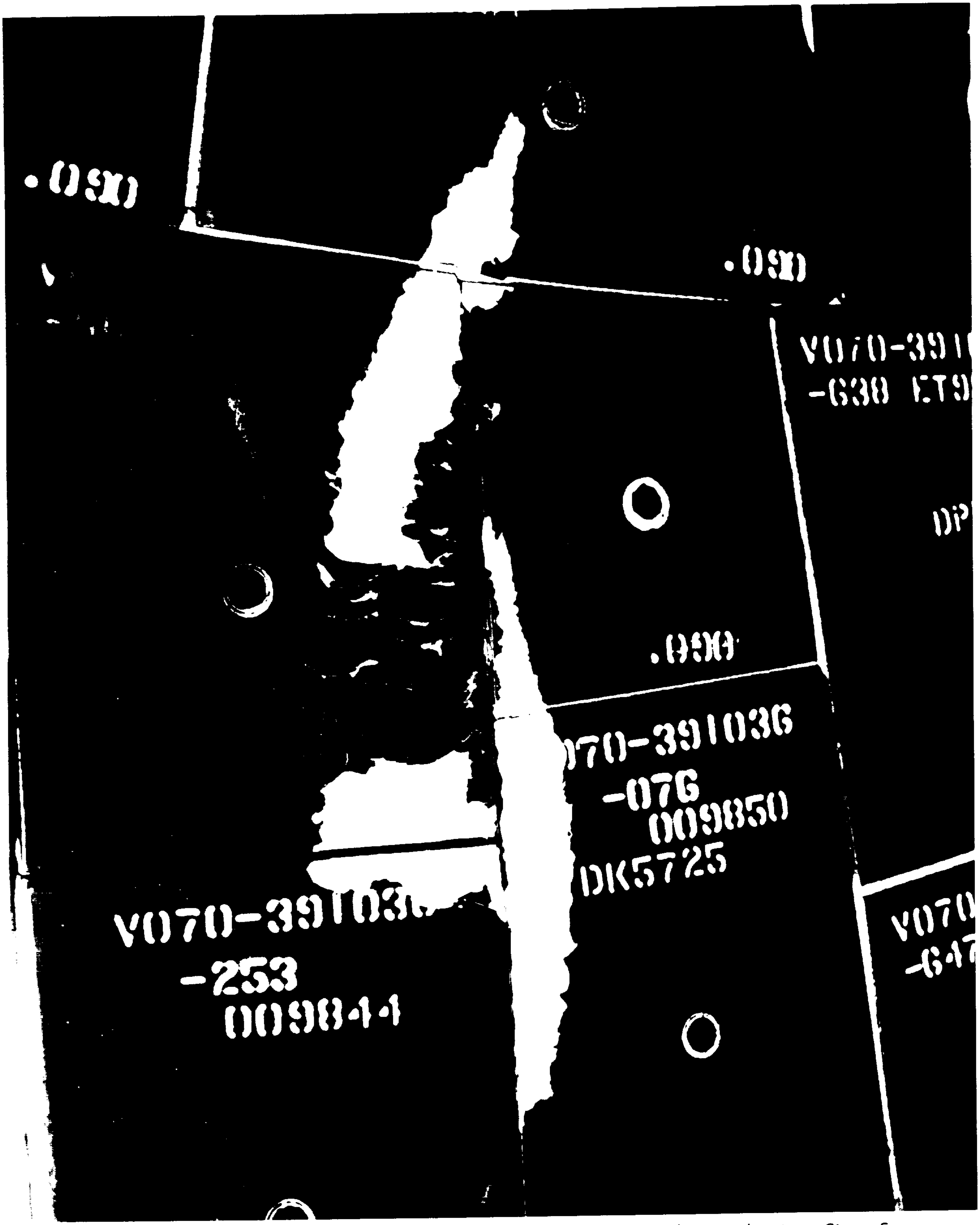
Post deploy positions of the drag chute compartment door, sabot with attached pilot chute bag, and pilot chute on the runway. Note white impact marks made by the drag chute compartment door.

The drag chute was located approximately 750 feet aft of the Orbiter and just to the right of the centerline. All drag chute hardware was recovered and showed no anomalies.

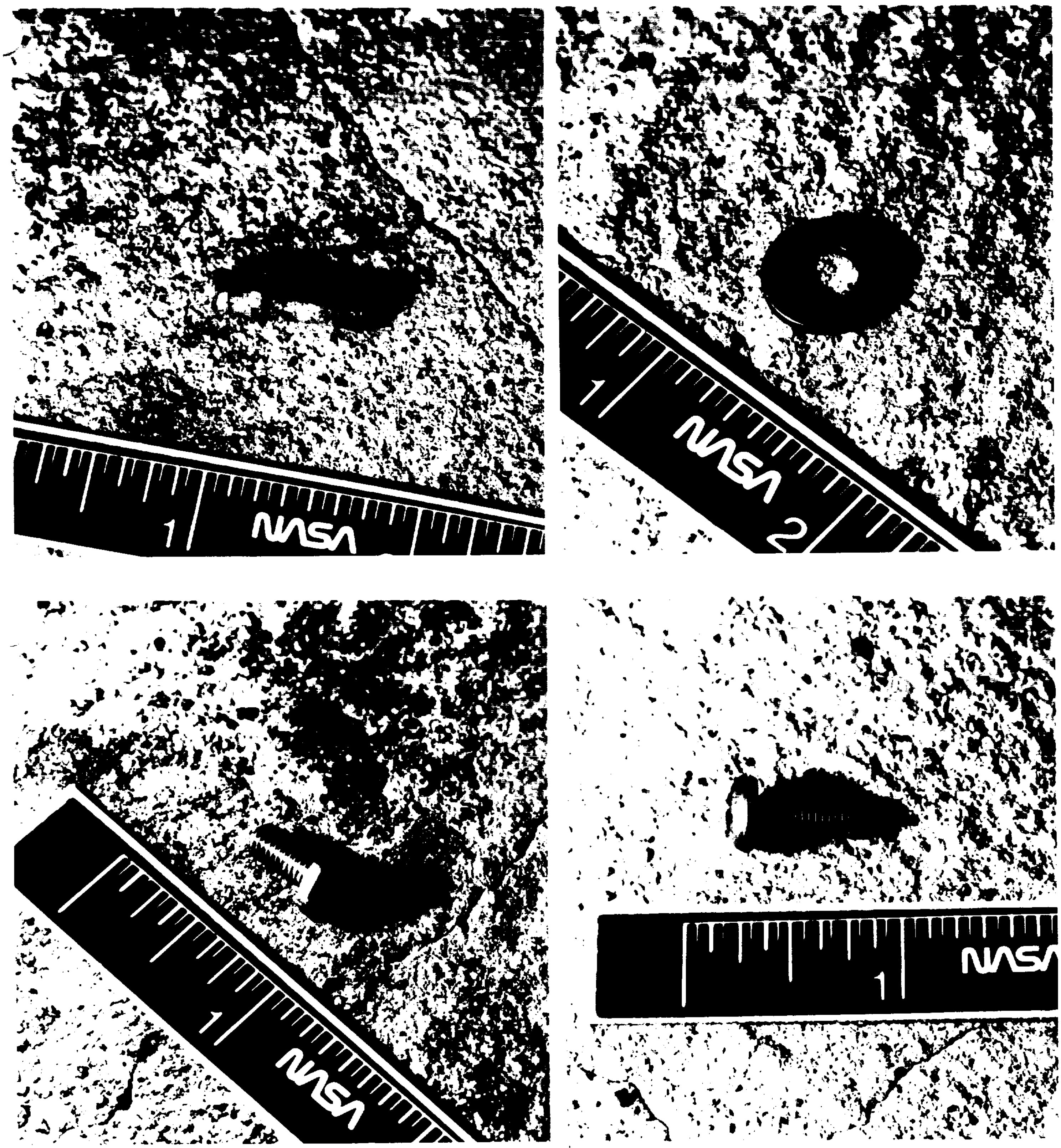


Overall view of Orbiter left side. Note discolored vent door #3

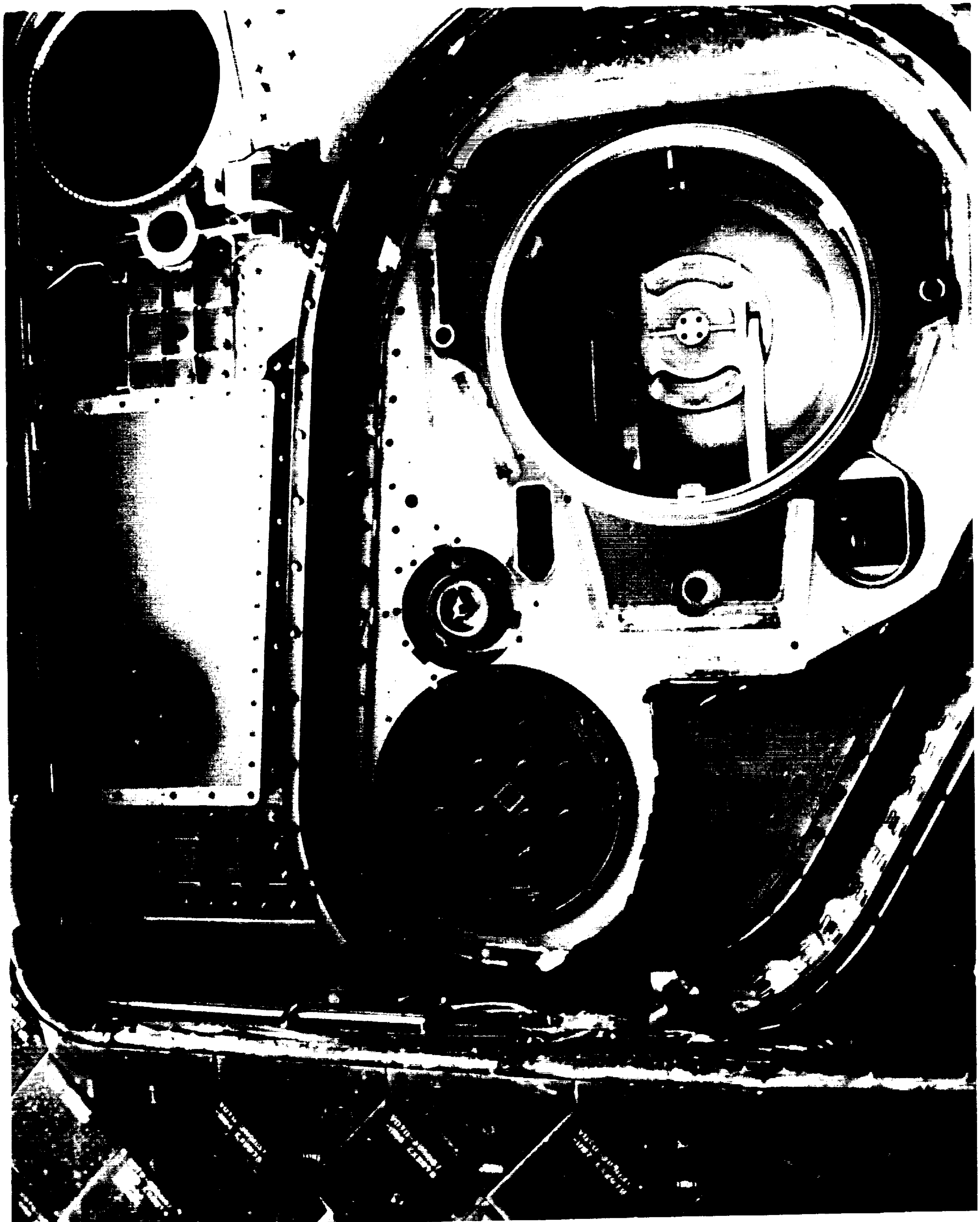
Overall view of Orbiter right side.
Note tile damage site just aft of the nose cap.



Tile damage site on the right side of the Orbiter just aft of the nosecap RCC measured 9-5/8 x 2-5/8 x 1/4 inches. The size and depth is indicative of an impact by a low density material such as External Tank TPS foam.



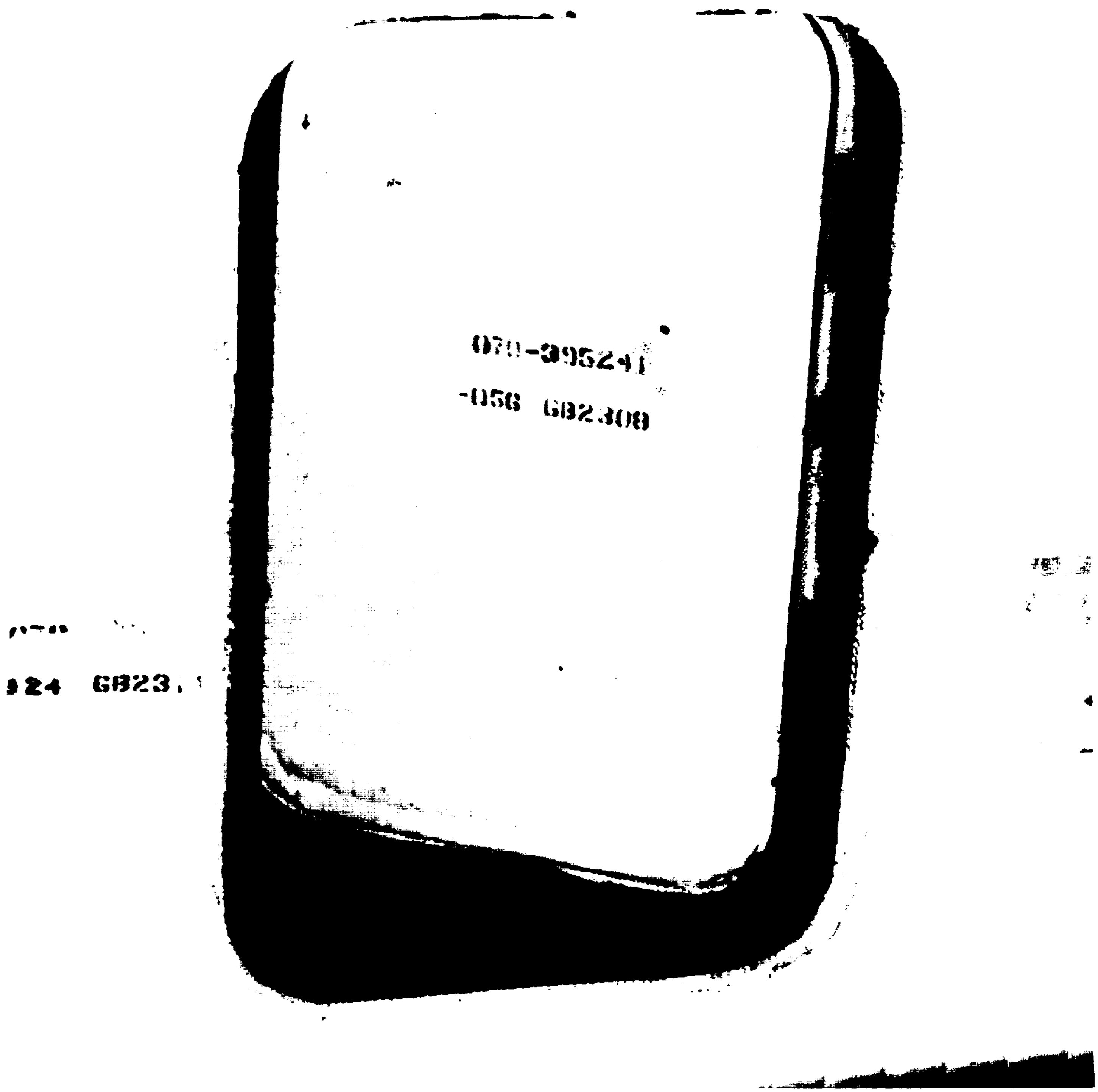
A segment of a Jo-bolt, a spacer (washer), and a Torx head screw were found on the runway under the RH ET/ORB umbilical door. A second Torx head screw lay on the runway under the LH ET door.



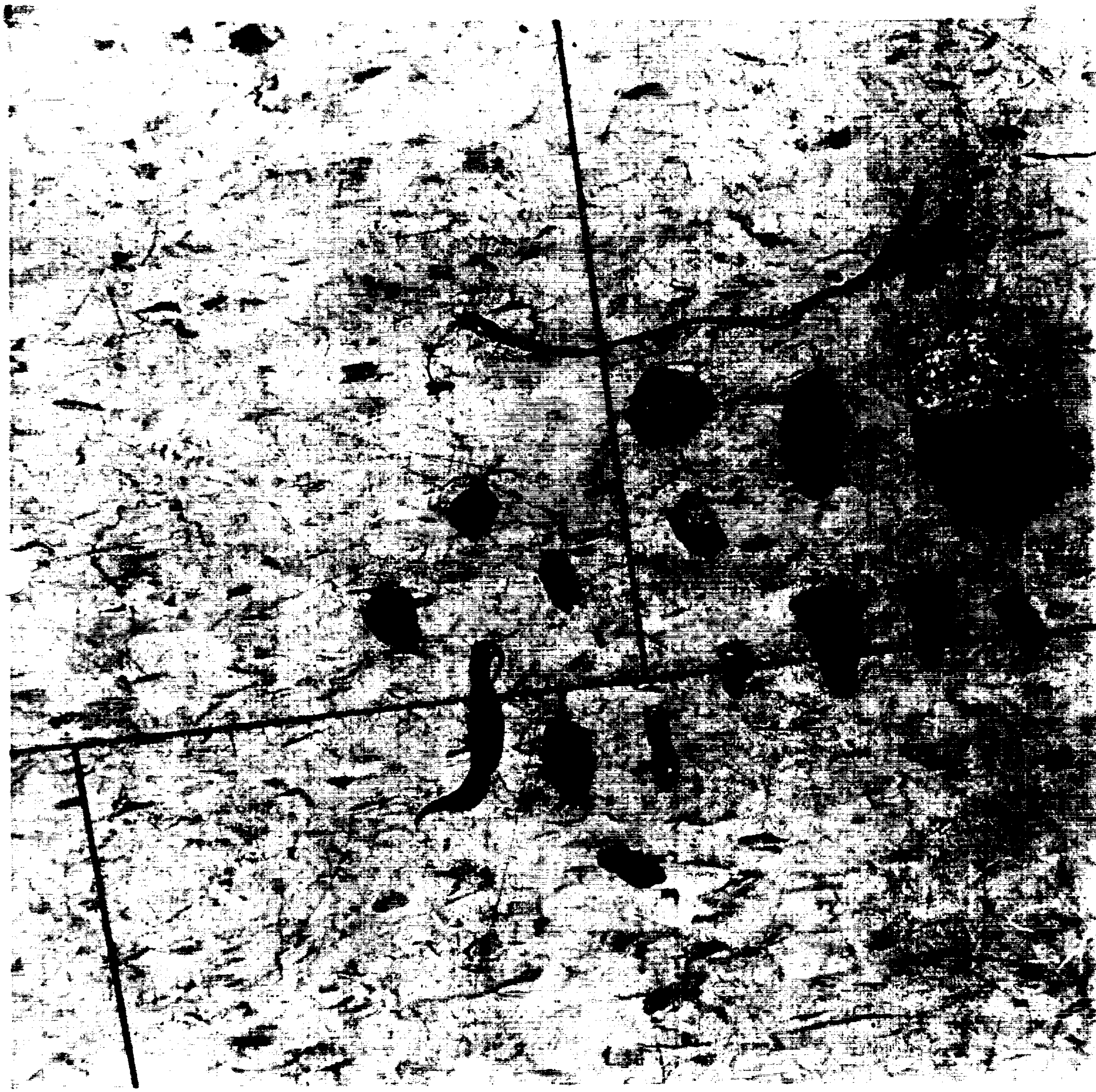
Overall view of the LO2 ET/ORB umbilical. All separation ordnance devices appeared to have functioned properly.

Overall view of the LH2 ET/ORB umbilical. All separation ordnance devices appeared to have functioned properly.

A small plastic bag was found lodged between the 16mm umbilical separation camera and the thermal window pane



Discoloration on RH vent door #9



Non-Orbiter debris collected from Runway 22 during the Post Landing Runway Debris Inspection

10.0 DEBRIS SAMPLE LAB REPORTS

A total of 19 samples were obtained from Orbiter OV-105 during the STS-49 post landing debris assessment at Ames-Dryden Flight Research Facility, California (Figure 25). The 19 submitted samples consisted of 9 window wipes, 5 wing leading edge RCC samples (2 LH, 3 RH), 1 residual sample from the lower surface body flap tiles, and 2 residual samples from Orbiter vent door #9 (LH/RH) discoloration. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involved the placing and correlating of sample particles with respect to composition, thermal (mission) effects, and availability. Debris sample results and analyses are listed by Orbiter location in the following summaries.

Orbiter Windows

Results of the window sample analysis revealed the presence of the following materials:

1. Metallics
2. RTV, silica tile, glass fibers, insulation
3. Paints, salt, rust
4. Organics and organic fibers
5. Earth compounds

Debris analysis provides the following correlations:

1. Metallic particles (zinc, aluminum, and carbon steel alloys) are common to SRB BSM exhaust residue, but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.

2. RTV, silica tile, glass fibers, and insulation originate from Orbiter TPS (thermal protection system).

3. Paint is of flight hardware/facility/GSE origin; salt is a naturally-occurring landing site product; rust is an SRB BSM exhaust residue.

4. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity. Organic fibers originated from the sample cloth used for sampling.

5. Earth compounds (muscovite, phosphorus, iron-silicon-calcium, and calcium-potassium rich materials and alpha-quartz) originate from the landing site.

Orbiter Wing RCC

Results of the Orbiter wing RCC samples indicated the presence of the following materials:

1. Silica tile, tile coating (black), RTV
2. Paint, rust, salt
3. Earth compounds
4. Organics and organic fibers

Debris analysis provides the following correlations:

1. Silica tile, black tile coating and RTV materials originate from Orbiter TPS (thermal protection system).

2. Paint is of flight hardware/facility/GSE origin; rust is an SRB BSM exhaust residue; and salt is a natural landing site product.

3. Earth compounds (muscovite, calcium-phosphorus, potassium-phosphorus materials) originate from the landing site.

4. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity. Organic fibers originate from the sample cloth used for sampling.

Body Flap Residue

Results of the body flap residue analysis reveals the presence of the following materials:

1. Tile, white tile coating, insulation, glass fiber, RTV
2. Paint, rust, salt
3. Earth compounds
4. Organics and organic fibers

Debris analysis provides the following correlations:

1. Tile, white tile coating, insulation, glass fiber and RTV originate from the Orbiter TPS (thermal protection system.

2. Paint is of flight hardware/facility/GSE origin; rust is an SRB BSM exhaust residue; and salt is a natural landing site product.

3. Earth compounds (calcium-phosphorus, calcium-potassium, iron-silicon-calcium) originate from the landing site.

4. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity. Organic fibers originate from the sample cloth used for sampling.

Orbiter Vent Door

Results of the Orbiter vent door #9 sampling indicated the presence of the following materials:

1. Metallics
2. Tile, black and white tile coating, glass fibers, RTV
3. Paint, dust, rust
4. Organics

Debris analysis provides the following correlations:

1. Metallics (aluminum-alloy) are common to SRB BSM exhaust residue, but are not considered a debris concern in this quantity (micrometer) and have not demonstrated a known debris effect.

2. Tile, black and white tile coating, glass fibers, and RTV originate from the Orbiter TPS (thermal protection system).

3. Paint is of flight hardware/facility/GSE origin; dust is of natural landing site origin; rust originates from SRB BSM exhaust.

4. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method. This detailed method is more difficult due to small sample size.

Conclusions

The STS-49 mission sustained Orbiter tile damage to a lesser than average degree. The chemical analysis results from post flight samples did not provide data that points to a single source of damaging debris.

Orbiter window samples exhibited evidence of SRB BSM exhaust, Orbiter TPS materials, landing site products, organics, and paint.

The Orbiter wing RCC sample results provided indications of SRB BSM exhaust, thermal protection system (TPS) materials, landing site products, and paint.

The Orbiter body flap residue sample results revealed evidence of Orbiter TPS materials, earth compounds, and paint.

The samples from Orbiter vent door #9 indicated exposure to SRB BSM exhaust, TPS materials, and paint.

Tabular formatting of the debris sample results as an aid in debris source identification was still under development at the time this report was released. This new type of debris analysis, i.e., repeatability of residual results (increase data populous) for identification of samples is designed to highlight trends.

11.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, there were no IFA candidates.

11.1 LAUNCH PAD/FACILITY

1. No items.

11.2 EXTERNAL TANK

1. No items.

11.3 SOLID ROCKET BOOSTERS

1. HDP #4 DCS plunger was obstructed by frangible nut halves.

11.4 ORBITER

1. No items.

Appendix A. JSC Photographic Analysis Summary

June 30, 1992

The following Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, STS-49 Final Report, and was completed June 30, 1992. Publication numbers are LESC-30231 and JSC-25826. The actual document can be obtained through the LESC library/333-6594 or Christine Dailey /483-5336 of the NSTS Photographic and Television Analysis Project.

2.0 Summary of the STS-49 FRF Film and Video Screening

2.1 Orange Discoloration in SSME #2 Exhaust Mach Diamond

(Cameras E-002, E-020, E-062, E-063, E-076, E-077, OTV-151)

Multiple (over sixty) orange discolorations were seen in the SSME #2 mach diamond during the engine test firing. The time period ranged from 15:11:57.343 to 15:12:11.735 UTC as seen on camera E-002. The orange discolorations typically lasted about 0.01 seconds. Figure 2.1 shows an example of the orange discoloration compared to the normal blue/white color of the SSME exhaust diamond.

2.2 Probable Tile Spacer Debris

(Cameras E-017, E-023, E-024)

A long, rectangular, red appearing object was seen coming from the base heat shield near the right OMS nozzle during the engine test firing. The object appeared to be a shim or spacer that came from between two tiles. Tile spacer debris was seen on previous missions STS-27R and STS-28R during SSME ignition. See figure 2.2.

An almost identical appearing long, rectangular, red object was also seen coming from the base heat shield between SSME #1 and the left OMS nozzle on camera E-024. This second object also appeared to be a spacer coming from between two tiles.

2.3 Orange Flashes in SSME Exhaust Plume

(Camera E-002, E-003, E-020)

A small orange flash was seen on the aft edge of SSME #1 exhaust plume near the mach diamond at 15:12:08.734 UTC. See figure 2.3. Orange flashes are often seen during SSME ignition prior to liftoff and have been attributed to small debris (ice or RCS paper) coming in contact with the hot exhaust gases.

Two orange flashes were noted off the rim of SSME #2 during the engine firing that were simultaneous with discolorations seen in the SSME #2 mach diamond (described in section 2.1) on camera E-020.

2.4 Base Heat Shield Deterioration

(Cameras E-023, E-024)

Tile surface material was seen to detach from a small area on the base heat shield at the base of the right OMS nozzle and fall aft as three separate pieces. See figure 2.4. A small area of base heat shield erosion was also noted at the base of the left OMS nozzle. Base heat shield erosion has been seen on previous missions from the camera E-023 and E-024 close-up views.

2.5 Loose Left OMS Nozzle Cover Tape

(Cameras E-020, E-024)

A piece of tape was seen to detach from the left OMS nozzle cover after SSME start up. See figure 2.5. The OMS cover remained secure during the test firing and the loose tape did not appear to cause any problems.

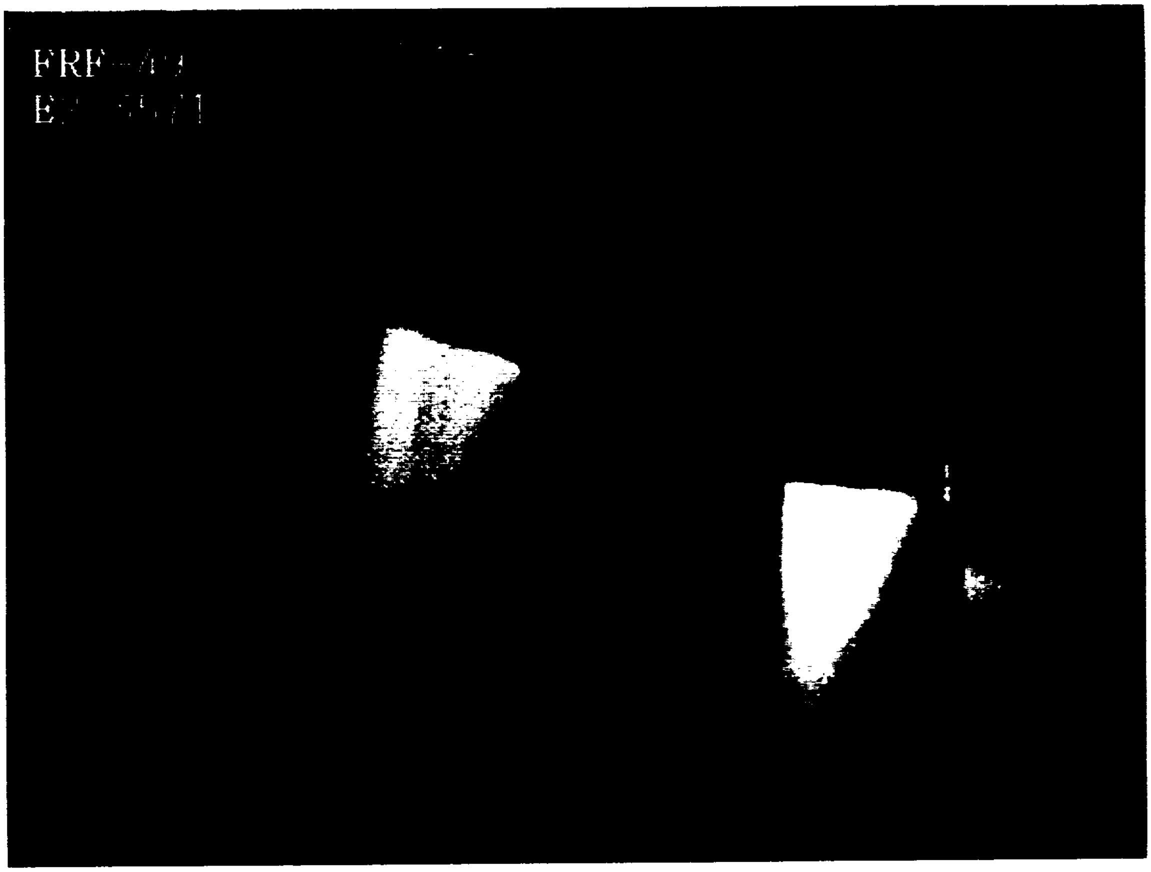


Figure 2.1 **Orange Discoloration in SSME #2 Exhaust Mach Diamond**

The orange discoloration in the SSME #2 mach diamond contrasts against the normal blue/white mach diamond color as shown above. Multiple (over 60) orange discolorations were seen in the SSME #2 mach diamond during the engine test firing. The orange discoloration typically lasted about 0.01 seconds.

Figure 2.2 **Probable Tile Spacer Debris**

A long, rectangular, red appearing object (white arrow) was seen coming from the base heat shield near the right OMS nozzle during the engine test firing. The object appeared to be a tile shim that dislodged from between two tiles. The green arrow points to an area of base heat shield erosion that occurred during the engine firing.

Figure 2.3 **Orange Flash in SSME Exhaust Plume**

A small orange flash was seen on the aft edge of SSME #1 exhaust plume at 15:12:08.734 UTC.

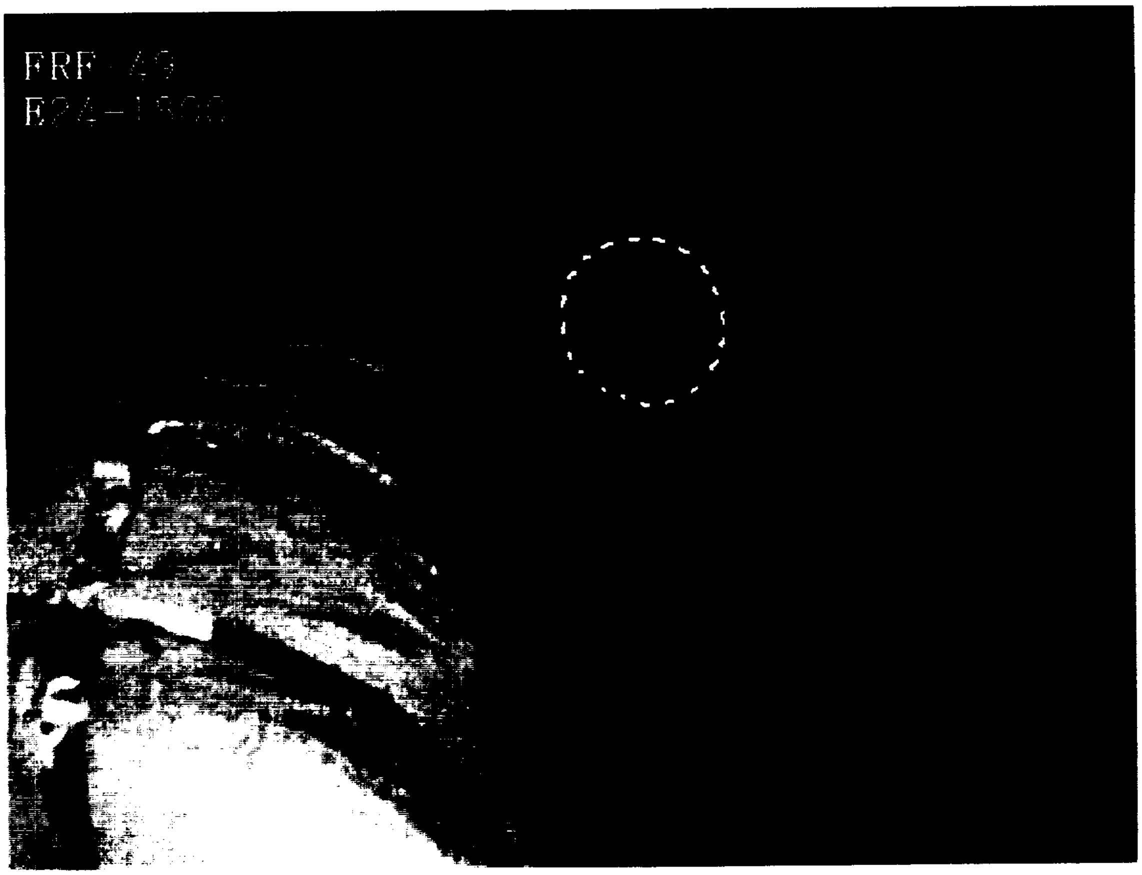


Figure 2.4 **Base Heat Shield Deterioration**

A small area of base heat shield erosion (circled) formed at the base of the left OMS nozzle during the engine firing. A second area of base heat shield erosion near the right OMS nozzle can be seen in Figure 2.2.

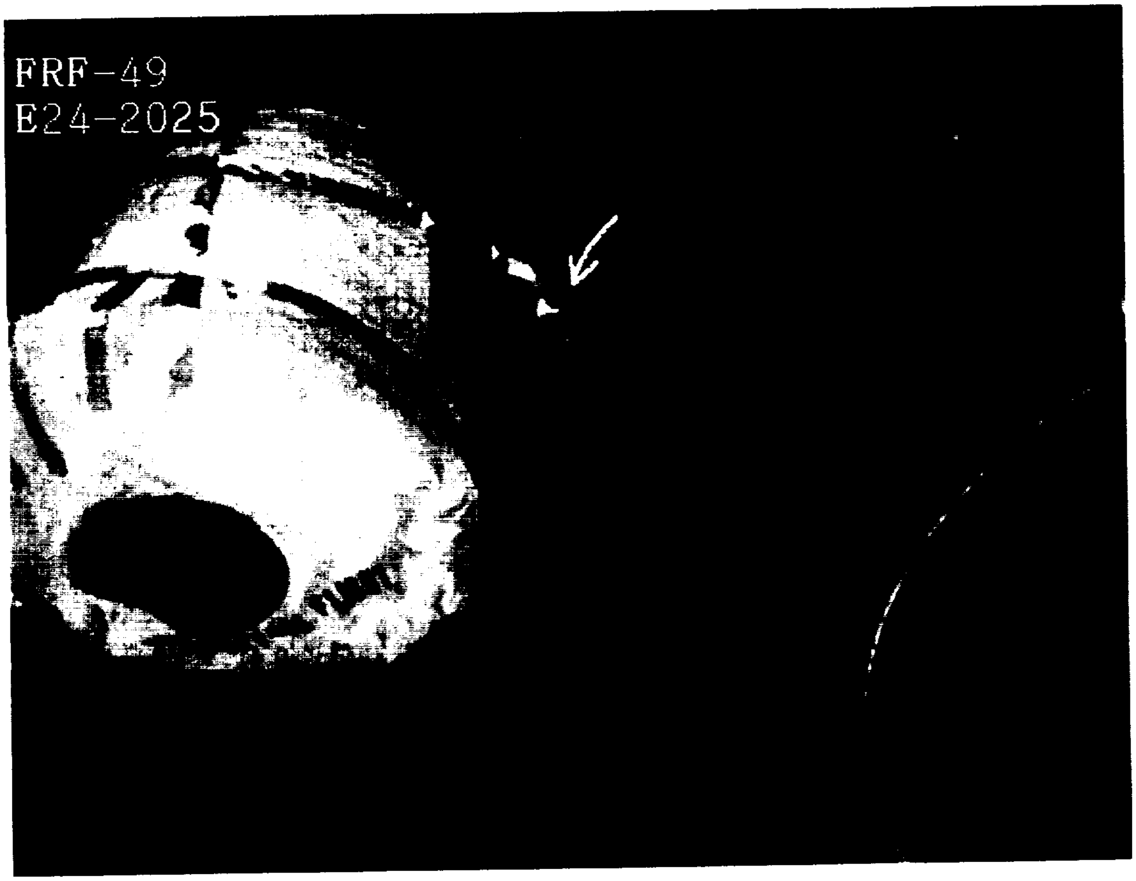


Figure 2.5 **Loose Left OMS Nozzle Cover Tape**

A piece of tape was seen to detach from the left OMS nozzle cover after SSME start up. The OMS cover remained secure during the test firing, however.

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2.0 Summary of the STS-49 FRF Film and Video Screening

2.6 Other Debris

Debris normally seen during SSME start up coming from the ET/Orbiter LH2 and LO2 umbilical disconnects, ice from the SSME engine vent line nozzles, the TSM LH2 and LO2 T-0 disconnects, and the ET GH2 umbilical vent line carrier were seen on many of the film/video views. See the individual film and video screening sheets in Appendix A for descriptions of the debris referenced by camera. None of the debris seen during the FRF film and video screenings were noted to cause damage due to impacts with Endeavour. Examples of some of the debris detailed in Appendix A are described below:

A dark, rectangular shaped piece of debris appeared to fall from on or near the base of the right ROFI ignitor and fall past SSME #3 during engine shut down on camera E-019. See figure 2.6 (A).

A elongated flat piece of debris, dark on one side and light on the other, fell aft between SSME #2 and #3 after SSME ignition. A irregular shaped object fell beneath SSME #1 during engine shut down. These events were noted on cameras E-020 and E-023. See figure 2.6 (B).

A long slender piece of dark debris was seen falling from behind the left RCS stinger near the time of engine start up on camera E-024. See figure 2.6 (C). A small piece of white debris noted coming from above SSME #2 appeared to come in contact with the SSME #2 vent line. No damage was observed. A fast moving piece of debris was seen to fall aft from behind the left OMS nozzle.

Multiple pieces of white debris (probably ice) were seen falling aft from the LO2 TSM carrier disconnect at SSME ignition on camera E-017F. Multiple pieces of large irregular shaped dark debris were in the field of view at the same time (possibly ice). The dark debris appeared out of focus and very close to the camera. See figure 2.6 (D). A red elongated object was noted coming from behind SSME #3.

A small piece of debris was seen falling near the rim of SSME #2 at 15:12:02.329 UTC on camera E-002. Small white debris was again noted falling aft of SSME #2 at 15:12:13.992 UTC.

Multiple pieces of small white debris were seen falling aft between SSMEs #1 and #3 during the engine firing. See Appendix A screening sheet for camera E-003 for the UTC times. A single piece of small white debris was seen near the left wing trailing edge, fell aft along the LH2 TSM, and landed on the MLP (15:12:14.642 thru 15:12:14.883 UTC). Small white debris from the LH2 T-0 TSM disconnect area fell aft along the SSMEs at 15:12:18.178 UTC.

A small piece of white debris was seen moving beneath the vehicle, under the right wing, and then in front of the LO2 TSM during the engine test firing on camera E-005.

A small piece of white debris, first seen near the ET attach brace, moved toward the vehicle and then broke into two pieces on the camera E-013F view. The separate pieces then fell past the left elevon and exited the right side of the view.

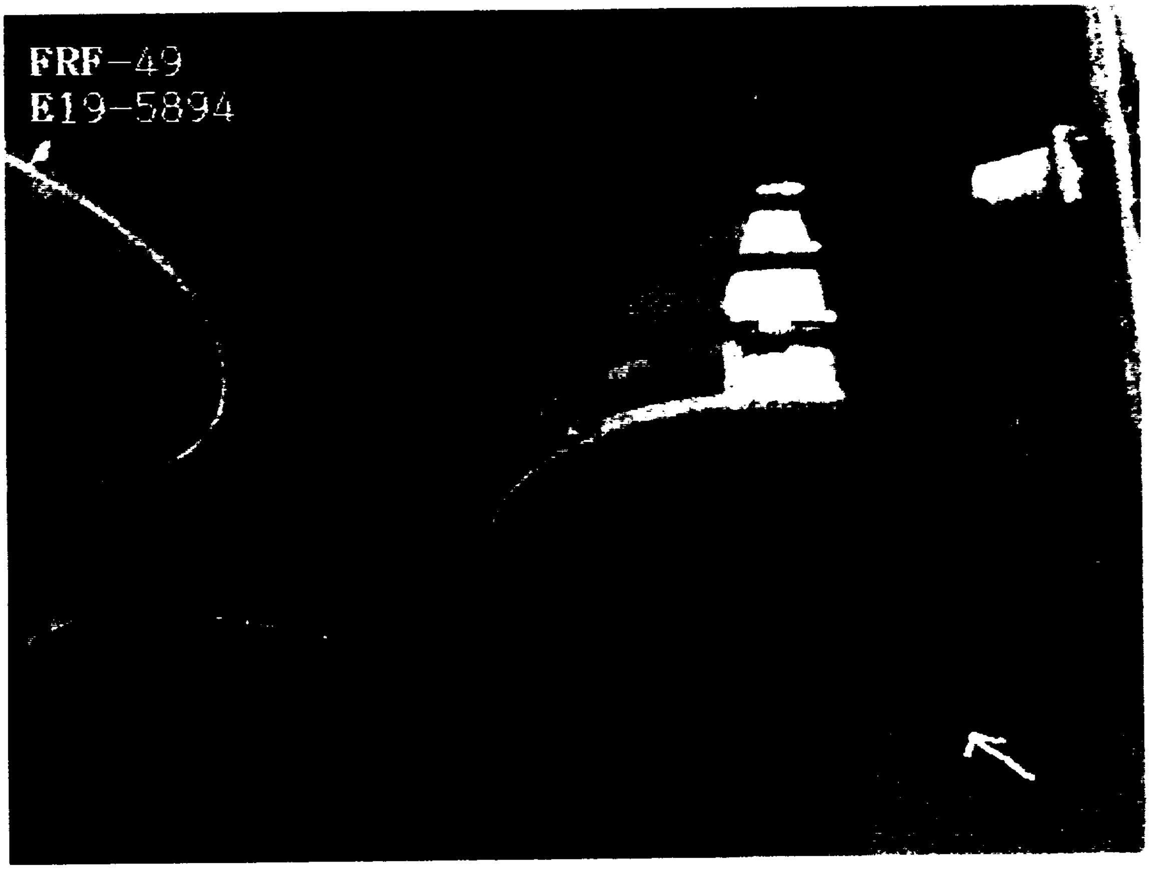

Figure 2.6 (A) **Dark Debris Near Right ROFI Ignitor**

A dark, rectangular shaped piece of debris was seen to fall from on or near the base of the right ROFI ignitor and fall past SSME #3 during engine shutdown.

Figure 2.6 (B) **Debris Falling Aft of SSME #1**

A irregular shaped object fell beneath SSME #1 during engine shutdown.

Figure 2.6 (C) **Dark Debris Falling From Behind Left RCS Stinger**

A long slender piece of dark debris was seen falling from behind the left RCS stinger near the time of engine startup.

Figure 2.6 (D) **Debris From LO2 TSM Carrier Disconnect**

Multiple pieces of white debris (probably ice) were seen falling aft from the LO2 TSM carrier disconnect at SSME ignition. The dark, out of focus objects (that appear to be in the foreground) are also probably ice from the disconnect.

2.0 Summary of the STS-49 FRF Film and Video Screening

2.7 Other Events

Other events noted during the FRF test firing include ET tip deflection (twang), the activation of the fire suppression water system, and birds in the field of view.

2.0 Summary of Significant Events Analysis

2.1 Debris

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 Umbilical Ice Debris

(Cameras E-001, E-002, E-004, E-005, E-006, E-017, E-018, E-019, E-024, E-026, E-031, E-033, E-034, E-050, E-065, E-076, E-077 and E-079)

The amount of ice debris from the LO2 and LH2 TSM T-0 umbilicals and the ET/Orbiter umbilicals was noted as normal on the MLP cameras. No follow up action has been requested.

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 SRB Holddown Post (HDP) Debris

(Cameras EX-004, E-011 and E-012)

On camera E-012, debris originated from the HDP M-5 shoe area. On camera EX-004, two pieces of dark debris (possibly epon shim or putty material as suggested by Rockwell-Downey) were noted between the SLV and HDP M-5 shoe at liftoff. A white tag was noted to the right of HDP M-7 at SSME ignition on camera E-011. No SRB holddown post stud hang ups were seen on any STS-49 mission films. No follow up action has been requested.

2.1.2.2 Debris near Vertical Stabilizer

(Cameras E-003 and E-020)

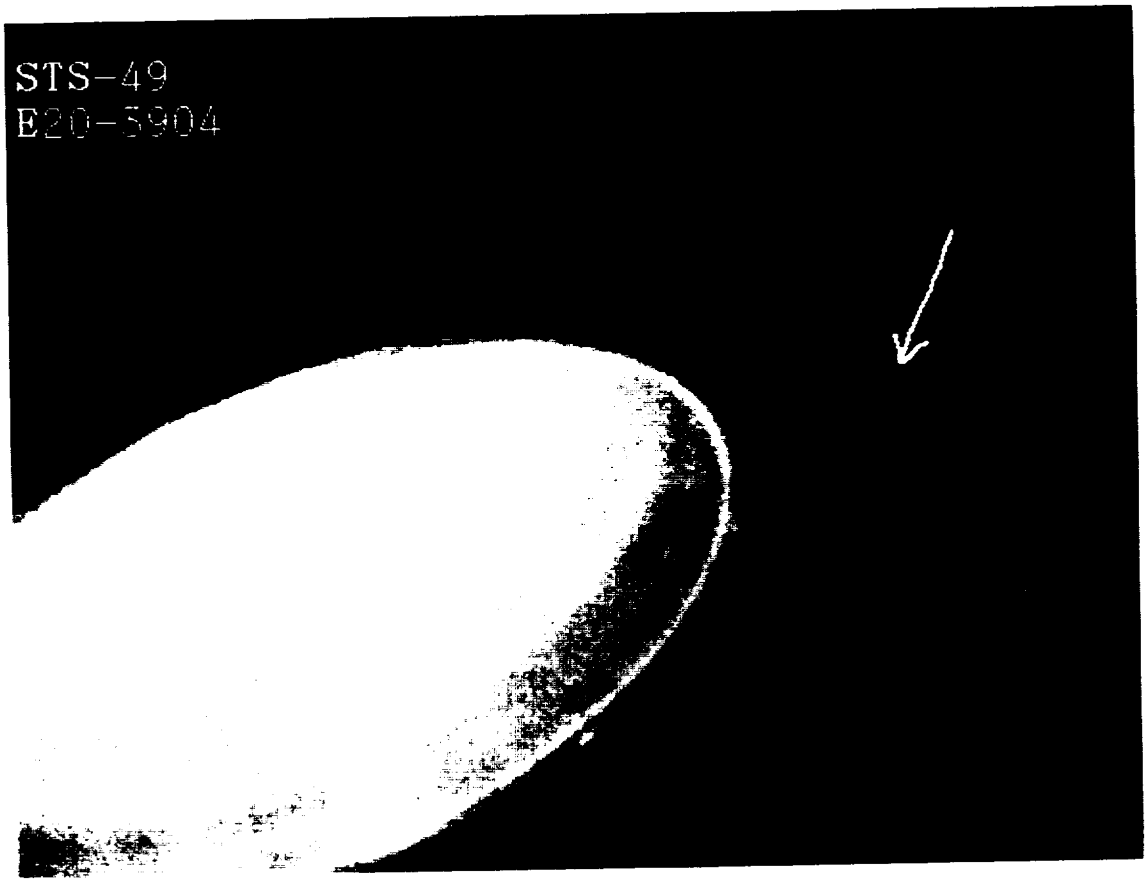

Figure 2.1.2.2 Debris near Vertical Stabilizer

A single piece of debris (dark on one side, light on the other) appeared on the right side of the FOV near the vertical stabilizer and fell aft into the SSME plume at liftoff. This debris is shown in figure 2.1.2.2. The event was shown to the TPS subsystem manager. No follow up action has been requested.

2.1.2.3 Flame Duct Debris

(Task #7)

(Cameras E-007, E-008, E-009, E-010, E-011, E-012, E-014 and E-062)

Since all the flame duct debris pieces were very small and the trajectories of these objects were very short or very difficult to see, Task #7, Velocity Measurements of SRB Duct Debris will not be performed this mission. (See Section 6.0, Appendix D.)

2.0 Summary of Significant Events Analysis

2.1.3 Debris after Liftoff
(Cameras E-005, E-006, E-025, E-031, E-052, E-054, E-077, E-079, and OTV-109)

2.1.3.1 Tumbling Debris seen on Underside of Orbiter
(Task #16)
(Cameras E-052, E-054, and E-079)

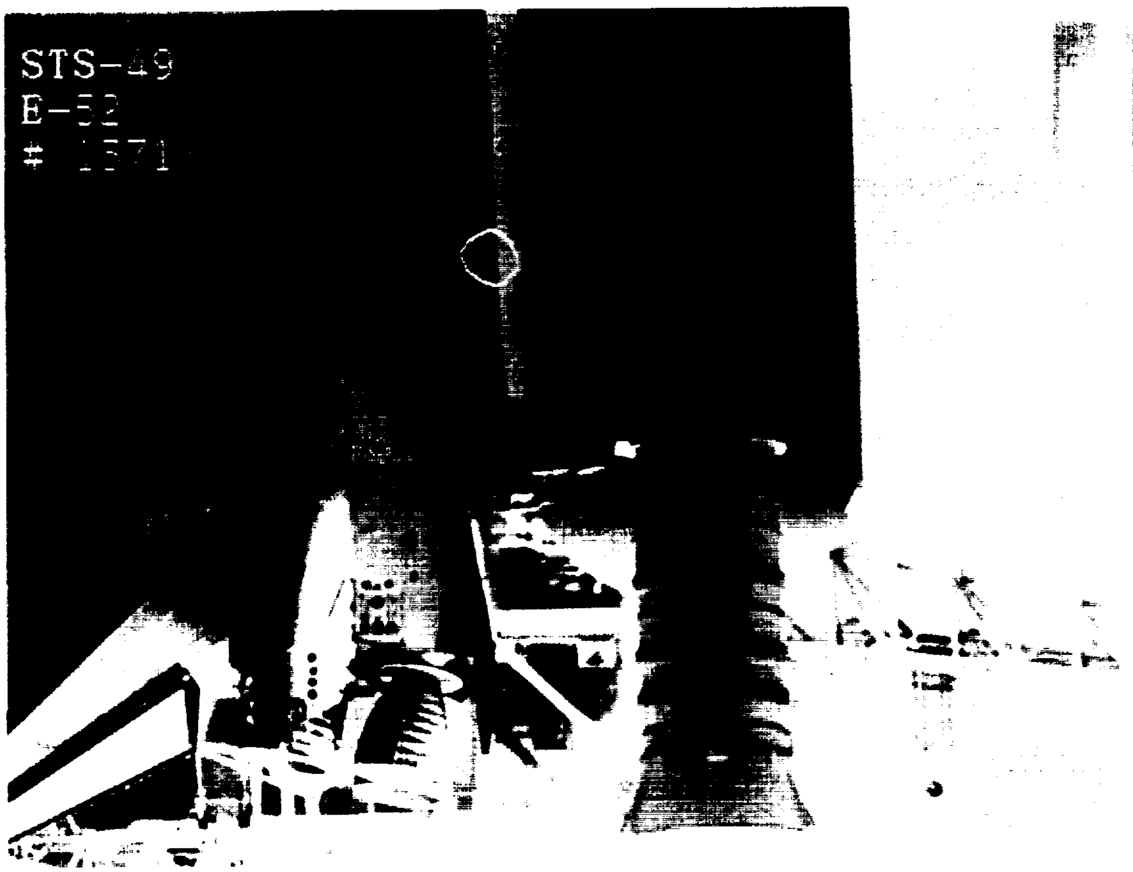

Figure 2.1.3.1 Tumbling Debris Seen on Underside of Orbiter

A tumbling piece of debris (dark on one side, light on the other), first noted on the underside of the Orbiter at mid-fuselage, fell aft during tower clear. This debris is depicted in figures 2.1.3.1. The distance from the tip of the Orbiter nose to the position that the debris was first seen was measured to be 36.3 feet (or 74.5 feet above the Orbiter umbilical area). This means that the debris source would have to have been at this position or further forward along the Orbiter x-axis. The actual source could not be determined visually from either cameras E-052 or E-054. (The LO2 feedline on the ET or the ET/Orbiter forward attach are both possible debris sources for this event as reported verbally by KSC. See Section 6.0, Appendix D, Task #16, Determine source of Debris on Underside of Orbiter at Mid Fuselage.)

A white piece of debris was on seen on camera E-079 moving from left to right across the ET LO2 feedline and then falling aft along the LO2 feed line at liftoff. This event was reviewed with a JSC

engineer and it was concluded that the debris was unlikely to be a piece of Orbiter tile. Also the post landing debris assessment report did not indicate a potential tile source for this debris.

Figure 2.1.3.2 **Rectangular Piece of Debris from Above LO2 Umbilical Area**
(Task #13)
(Cameras E-005, E-006, and E-025)

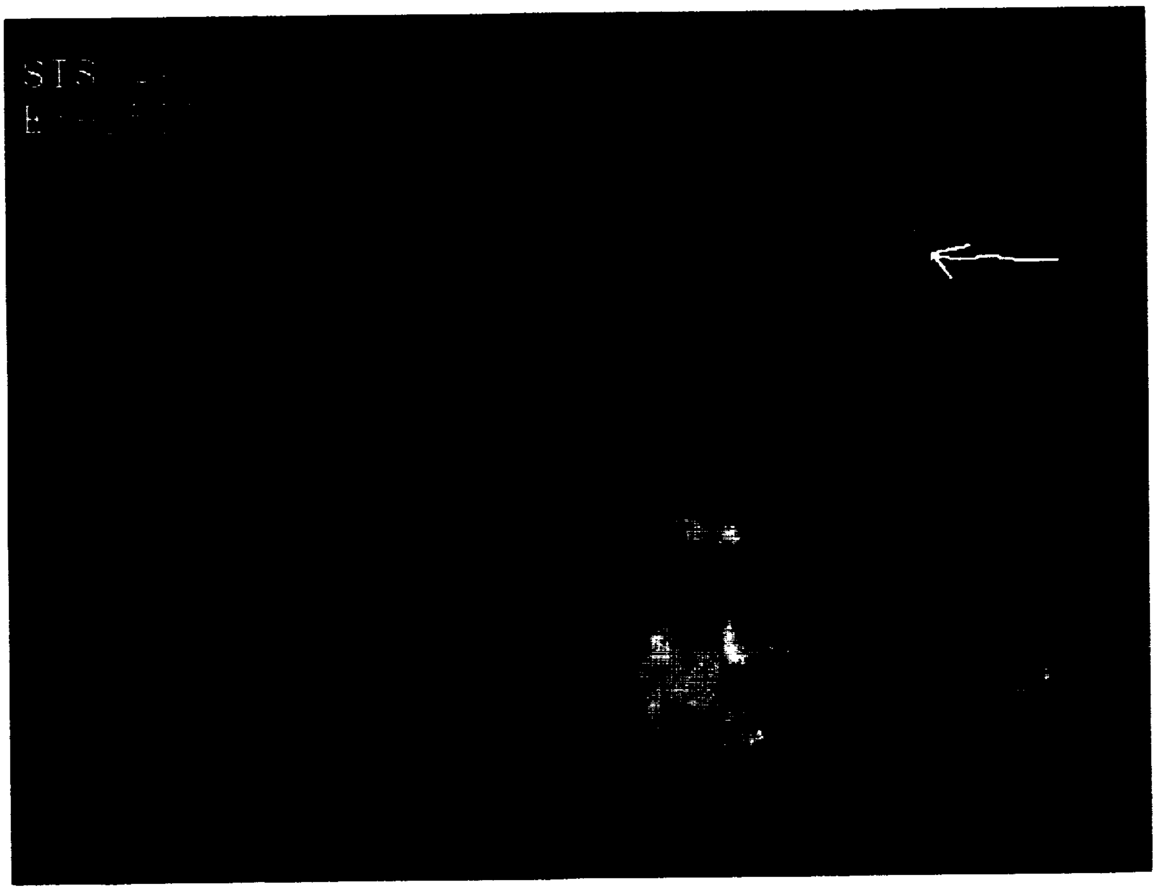

Figure 2.1.3.2 **Rectangular Piece of Debris from Above LO2 Umbilical Area**

A light, medium-sized piece of rectangular debris along with two other pieces of debris were seen originating from above and outboard of the LO2 umbilicals on cameras E-005, E-006 and E-025. See figure 2.1.3.2. This debris fell aft past the right inboard elevon at liftoff. Analysis indicated that the debris was probably ice from the LO2 feedline on the external tank. See Section 6.0, Appendix D, Task #13, Rectangular Debris Characterization.

Figure 2.1.3.3 **Two White Pieces of Debris in front of Right Outboard Elevon**
(Camera E-077)

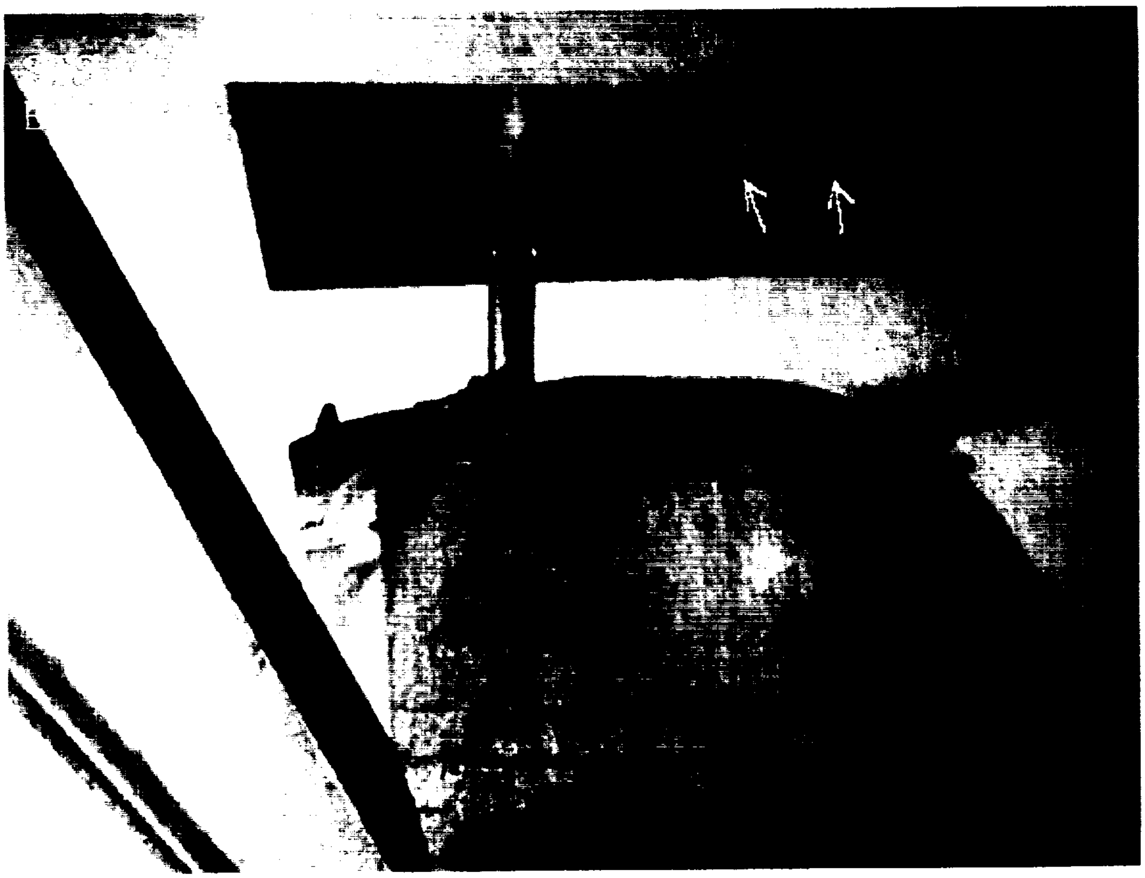

Figure 2.1.3.3 **Two White Pieces of Debris in front of Right Outboard Elevon**

Two small pieces of white debris were seen falling aft of the edge of the right inboard elevon at liftoff on camera E-077 as seen in figure 2.1.3.3. No follow up action has been requested.

Figure 2.1.3.4 **Debris from above LH2 Umbilical and from Aft Strut** *(Cameras E-031 and OTV-109)*

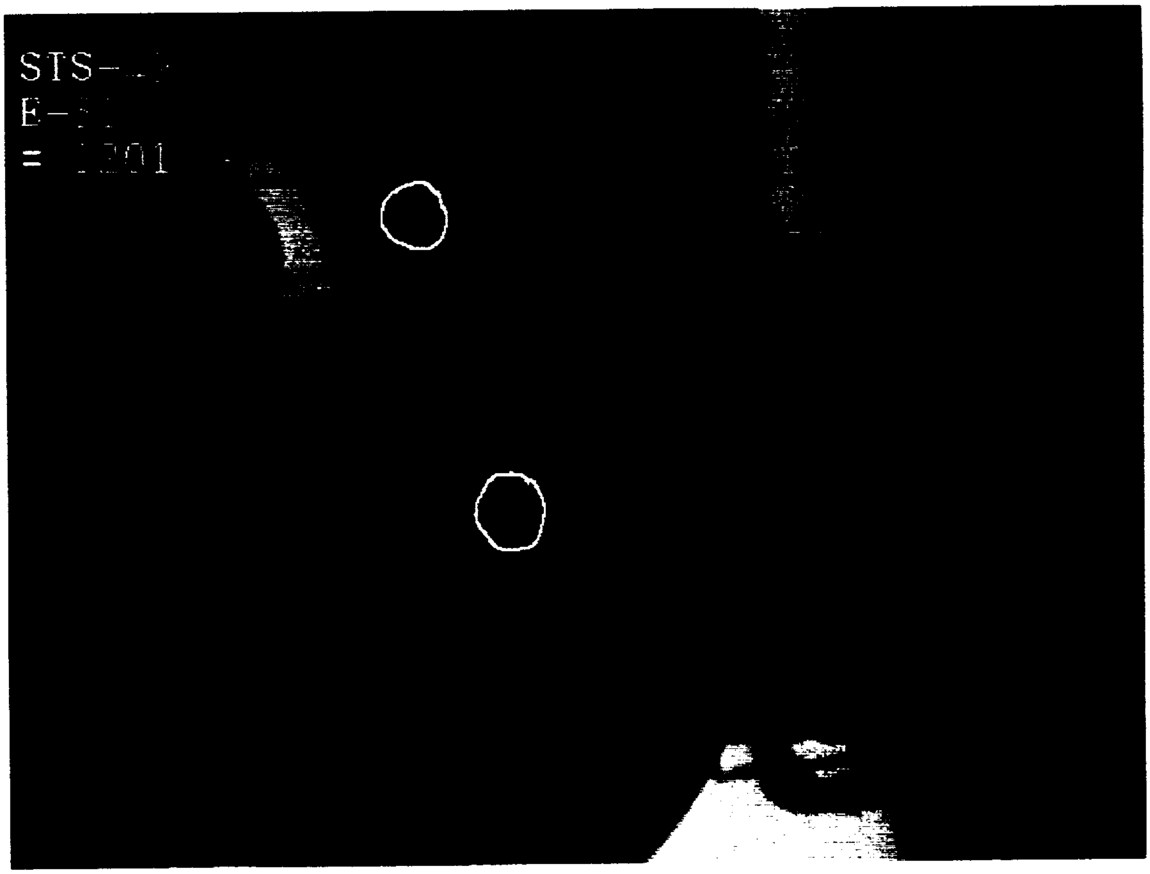

Figure 2.1.3.4 **Debris from above LH2 Umbilical (top circle); Debris from Aft Strtut (lower circle).**

White debris (possibly ice) originated from the the ET side of the aft attach strut and fell toward the pad at liftoff as seen on OTV-109 and E-031. See figure 2.1.3.4.

Debris falling aft of the SLV after liftoff was similar to that seen on previous mission's film and videos. The timing of selected debris events is presented in Section 6.0, Appendix C, STS-49 Timing Data Report.

None of the debris described above was seen to strike the launch vehicle. No further analysis has been requested.

2.0 Summary of Significant Events Analysis

2.2 MLP Events

2.2.1 Base Heat Shield Flexing

(Cameras E-019, E-020, E-076 and E-077)

Flexing (characterized by an up and down motion) was noted in the base heat shield from cameras E076, E-077, E-019, and E-020. The flexing occurred at approximately T -4.6 seconds and ended just after all SSMEs had finished starting up at about T -2.9 seconds MET. Note that the flexing in the base heat shield was seen in the area between the SSMEs.

In order to see if the base heat shield flexing as seen on STS-49 was unique to OV-105, previous missions were screened. Base heat shield flexing was detected on STS-51J (first flight of OV-104), STS-33, STS-48, STS-45, and STS-49 FRF. According to KSC, base heat shield flexing was also observed on the STS-1 FRF (SSME test firing for first flight of OV-102), STS-6 (FRF1 and FRF2) and STS-6 (first flight of OV-099), STS-14 (slightly evident), and STS-28 FRF. According to Rockwell - Downey base heat shield flexing was also seen on STS-41D, STS-51F, and STS-51J FRF.

Since base heat shield flexing has been seen on previous vehicles it is not unique to OV-105 and may be a normal occurrence.

An analysis was conducted to measure the amount of up an down motion exhibited in the base heat shield flexing by using film from camera E-076. Three separate analysts determined distances from a point on the base heat shield to a control point on the base of the vertical stabilizer over the same 200 frames for which maximum base heat shield movement was observed. The average of the distances from the three analysts was then used to determine the best estimate of the "true" distance for each frame. The distances between successive extreme points were measured and the maximum peak to peak displacement was found to be 1.06 inches with a 95% confidence range of between .24 to 1.88 inches. Note that the overall distance between the base heat shield and the point on the vertical stabilizer increases about 2 inches over the last one second and this is thought to be due to the twang caused by SSME start-up.

The frequencies of the oscillations seen in the base heat shield flexing were measured and two high frequency peaks were detected at 25 Hz. and 41 Hz.

The displacement of a point on the base heat shield was also measured with respect to the X and Y axes of the camera (note that the Y axis of the camera is essentially the same as the Orbiter's X axis and the X axis of the camera is at a 30 degree angle to the orbiter's Y axis). The maximum peak to peak displacements are approximately 1.3 inches for each axis with a 95% confidence interval for the Y displacement of between 0.4 and 2.3 inches and for the X displacement the 95% confidence interval is between 0.3 and 2.2 inches.

MSFC conducted an analysis of the base heat shield flexing and found that the maximum displacement in the Orbiter X and Y axes was approximately one inch. The MSFC preliminary report is included in Section 6.0, Appendix D, Task #14, Characterize Base Heat Shield Motion at SSME start-up.

A frequency analysis was conducted on the X and Y displacements and no dominant high frequencies were detected, implying that the base heat shield flexing is occurring randomly. This

result contradicts the finding of apparently strong peaks using the control point to base heat shield distance data. Since the distance data incorporates both X and Y displacements, it could be showing that peaks in the X and Y combine to create stronger peaks in the distance data.

MSFC also conducted a frequency analysis and found no dominant frequencies. MSFC concluded that the flexing was essentially random.

2.2.2 Base Heat Erosion
(Cameras E-019, E-023 and E-024)

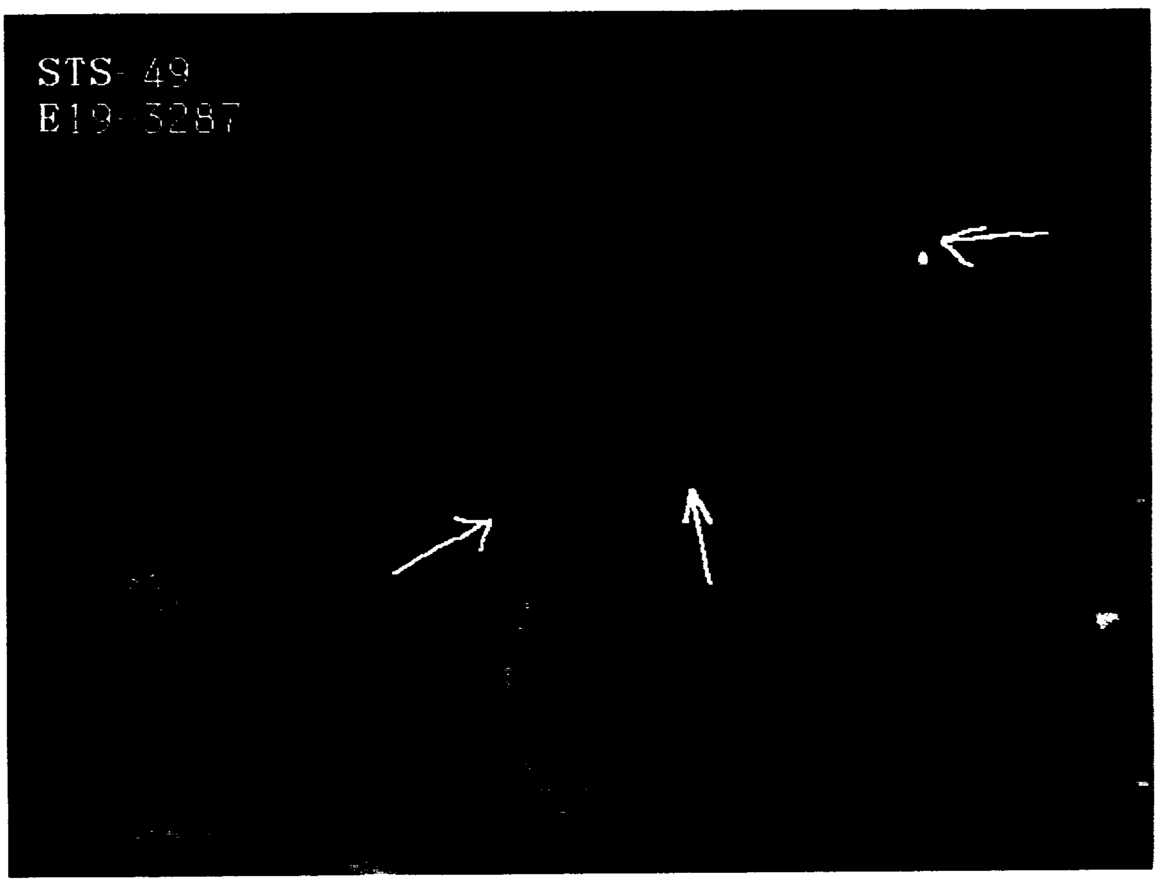

Figure 2.2.2 Base Heat Shield Deteoration on the Base of the Right RSC Stinger

Base heat shield erosion (three chips) were noted on cameras E-019, E-023 and E-024 on the right RCS stinger and at least seven small chips were noted on the base heat shield and left RCS stinger base at SSME start up as seen in figure 2.2.2. No further analysis has been requested.

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2.2.3 Orange Vapor (Possible Free Burning Hydrogen)
(Cameras OTV-170, E-001, E-002, E-003, E-005, E-016, E-018, E-019, E-020, E-036 and E-077)

Orange vapor (possibly free-burning hydrogen) was seen to rise toward the base of the vertical stabilizer just prior to SSME ignition. This vapor appeared to be similar to other missions with winds from the north. No further analysis has been requested.

2.2.4 Flashes in SSME Plumes
(Cameras E-003 and E-005)

Multiple flashes were seen in the SSME #1, #2 and #3 exhaust plumes after SSME start-up while the vehicle was still on the pad. These flashes have been seen on previous missions. No further analysis has been requested.

2.3 Ascent Events

2.3.1 White Spot on Underside of Orbiter TPS at Liftoff
(Camera E-034)

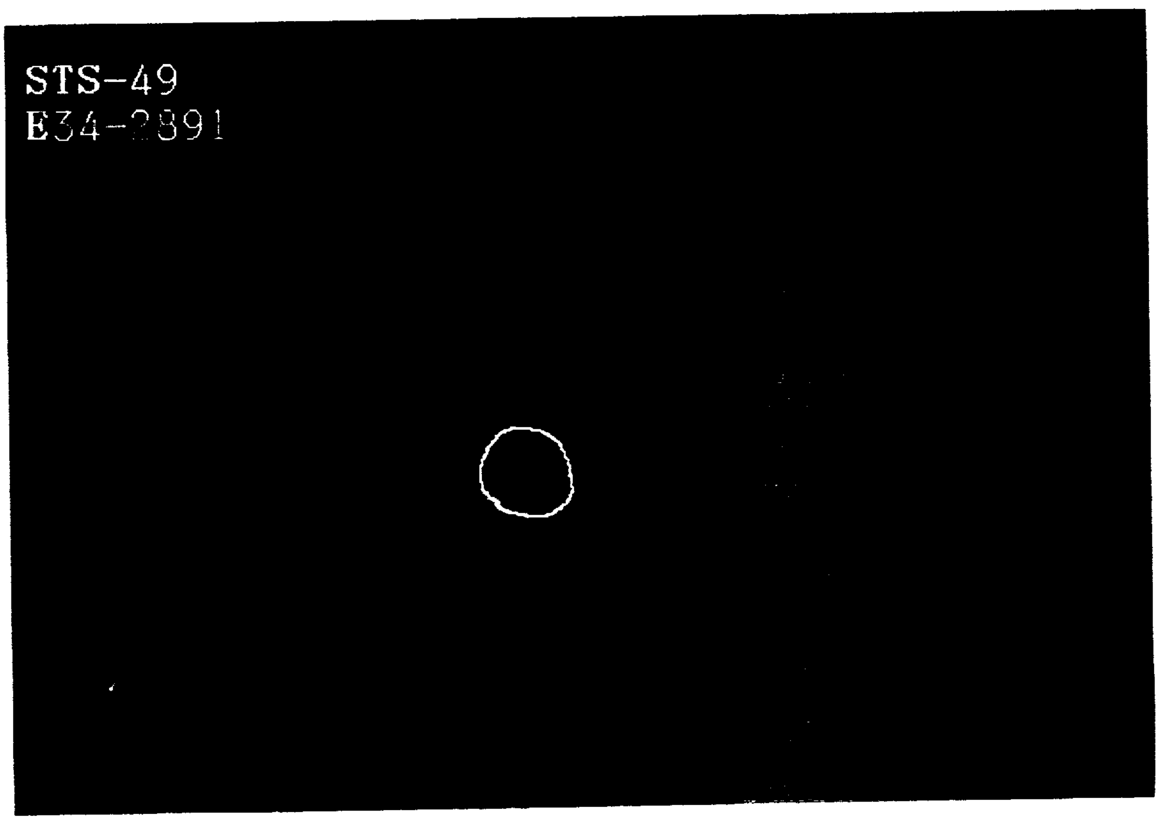


Figure 2.3.1 **White Spot on Underside of Orbiter TPS at Liftoff**

A white spot was noted on the underside of the Orbiter (approximately at mid-fuselage on the right side) at liftoff and appeared to be on the Orbiter TPS. See figure 2.3.1. This white spot was not seen from any other launch views. Inspections of the Orbiter after landing did not show the spot. No further analysis has been requested.

2.3.2 Brightening in SRB Plume
(Cameras ET-212 and E-204)

A small area near the upper right corner of the SRB plume appeared to brighten intermittently between 45 and 87 seconds MET. This was noted on camera ET-212.

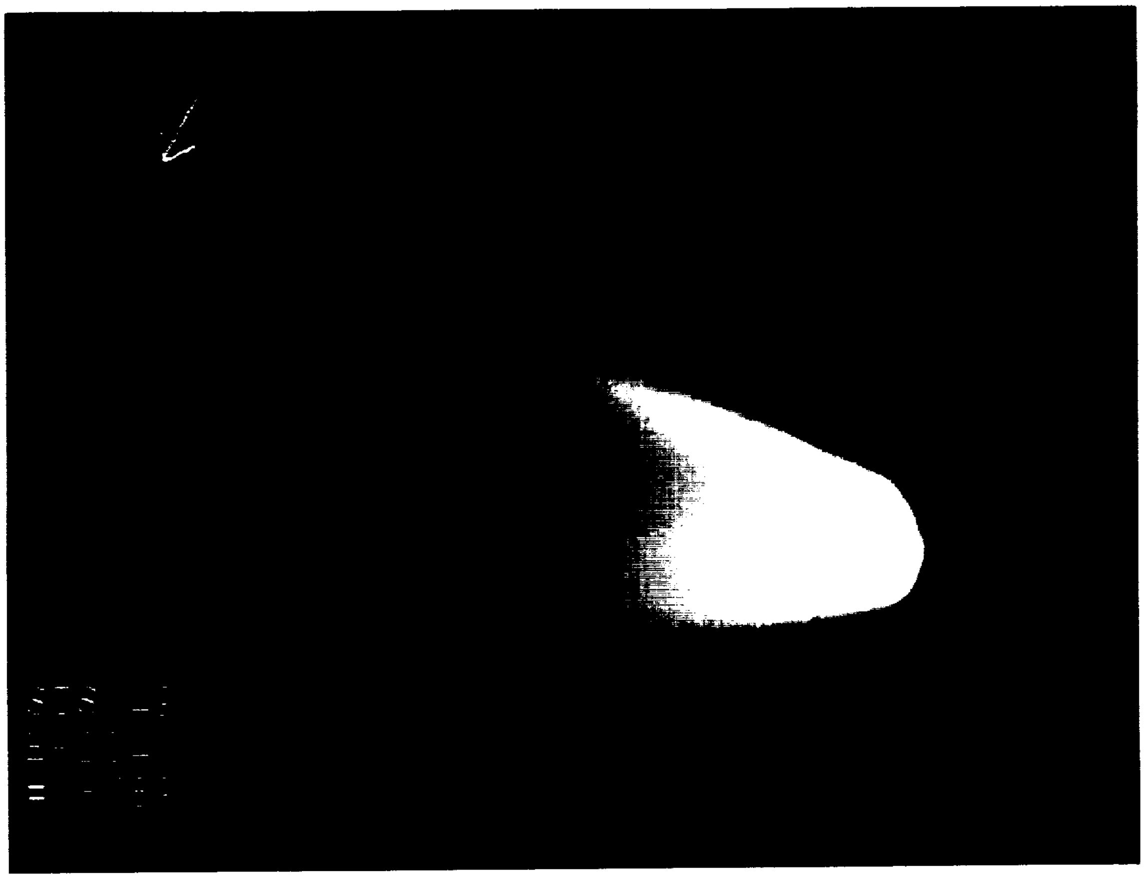
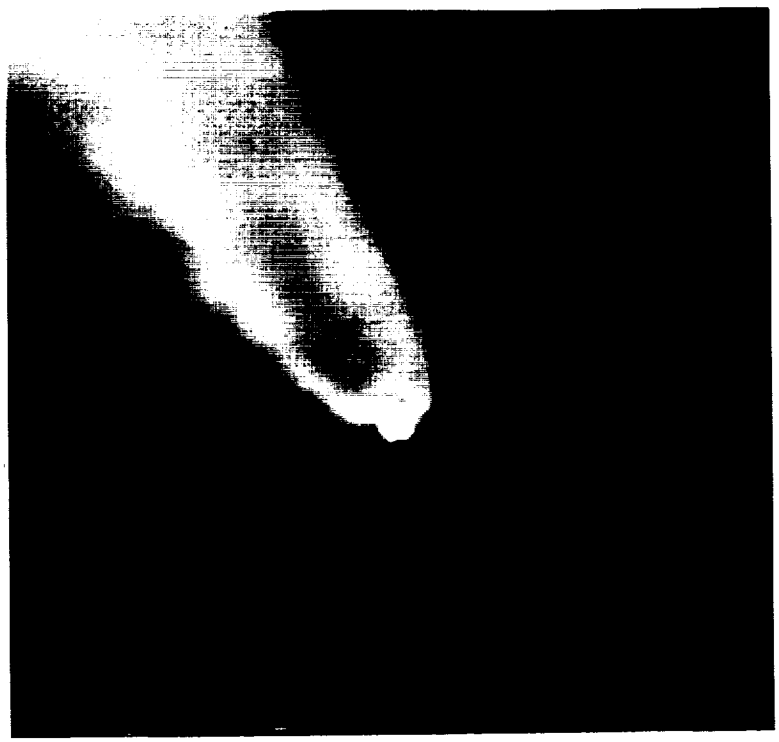


Figure 2.3.2 Bright Orange Area in SRB Plume

A bright orange area was observed at 121 seconds MET in the SRB plume several vehicle lengths below the vehicle as seen in figure 2.3.2. This bright area may have been the result of slag at tailoff prior to SRB separation.

2.3.3 Flares in SSME Plume

(Task #12)
(Cameras KTV-5, E-208, E-212, E-218, and E-220)



2.3.3 Orange Discoloration in SSME Plume

Up to five separate flares were seen in the SSME exhaust plume after liftoff on the long range trackers including a single flare that was noted on camera ET-212 near the SSME #1 plume at 48 seconds MET. Flares during this time period have been seen on several earlier missions and no further analysis has been requested.

Twenty-six orange discolorations (possibly flares) were noted in the SSME plumes beginning at 84 seconds MET (See Section 6.0, Appendix D, Task #12, Flare in SSME plume starting at 84 seconds MET.) and continuing through SRB separation. Figure 2.3.3 is an example of one of the twenty-six orange discolorations. This event occurred at 118.7 seconds MET. The first of these orange discolorations coincided with a large increase in the SSME #2 high pressure fuel pump temperature reported by the MER. (It was later reported by the MER that this high pressure report was a sensor failure, not an actual high temperature condition.) Normal recirculation seen on camera ET-212 between 91 and 106 seconds MET was compared to the events seen on KTV-5. Since STS-33 was also launched from Pad 39B at a similar inclination angle and launch time, KTV-5 was reviewed for similar discolorations and did not show the same flare event; however color distortions were present on STS-33 KTV-5 view of the SLV at about the same viewing angles.

The STS-49 D2 tape of KTV-5 was screened at the JSC Imagery Operations Office/JL5 in order to get a better view of the discolorations in slow motion. JL5 reported that camera KTV-5 had a four line vertical jitter that was introduced at the time of recording at launch and it was impossible to remove. The view of the sensor "lag" on the D2 was very apparent. It is believed that the discoloration events were, at a minimum, exaggerated by the sensor lag making them appear so distinctive. Similar discolorations were not seen on other cameras. The conclusion was that the discolorations on KTV-5 were due to vertical jitter. No further analysis was requested.

2.3.4 Body Flap Motion

(Cameras E-17, E-212 and E-220)

Slight body flap motion was seen on camera E-017 prior to liftoff. Slight body flap motion was also seen on camera films E-212 and E-220 after liftoff. Body flap motion has been seen on previous mission films and the magnitude of the body flap motion seen on the STS-49 views was not sufficient to warrant further analysis. See Section 6.0, Appendix D, Task #4, Body Flap Analysis.

2.3.5 Recirculation

(Task #1)

(Cameras ET-212, E-204, E-212 and E-218)

Recirculation prior to SRB separation was seen on long range cameras ET-212, E-204, E-212 and E-218. The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all of the previous missions. For STS-49, the start of recirculation was observed at about 93 seconds MET and the end was noted at approximately 110 seconds MET on Camera E-212. Timing data for recirculation for STS-49 is presented below and a summary of recirculation for previous missions is presented in Section 6.0, Appendix D, Task #1, Recirculation Characterization. No further analysis has been requested.

<u>Cameras on which recirculation was observed for STS-49</u>

CAMERA	START (seconds MET)	STOP (seconds MET)
ET-212	91	106
E-204	---	---
*E-212	93	110
E-218	93	101

* **BEST VIEW OF RECIRCULATION**

NOTE: **Intermittent LOV of the area due to the exhaust plumes prevented acquisition of specific start and stop times for recirculation on camera E-204**

2.3.6 Linear Optical Effect

(Camera E-205 and E-212)

On cameras E-205 and E-212, linear optical distortions were noted at 57 and 60 seconds MET. The time of occurrence of these and other events during ascent are presented in Section 6.0, Appendix C, STS-49 Timing Data Report. Linear optical effects have been seen on previous missions. No follow up action has been requested.

2.0 Summary of Significant Events Analysis

2.3.7 SRB and ET Separation

(Camera UMBL1)

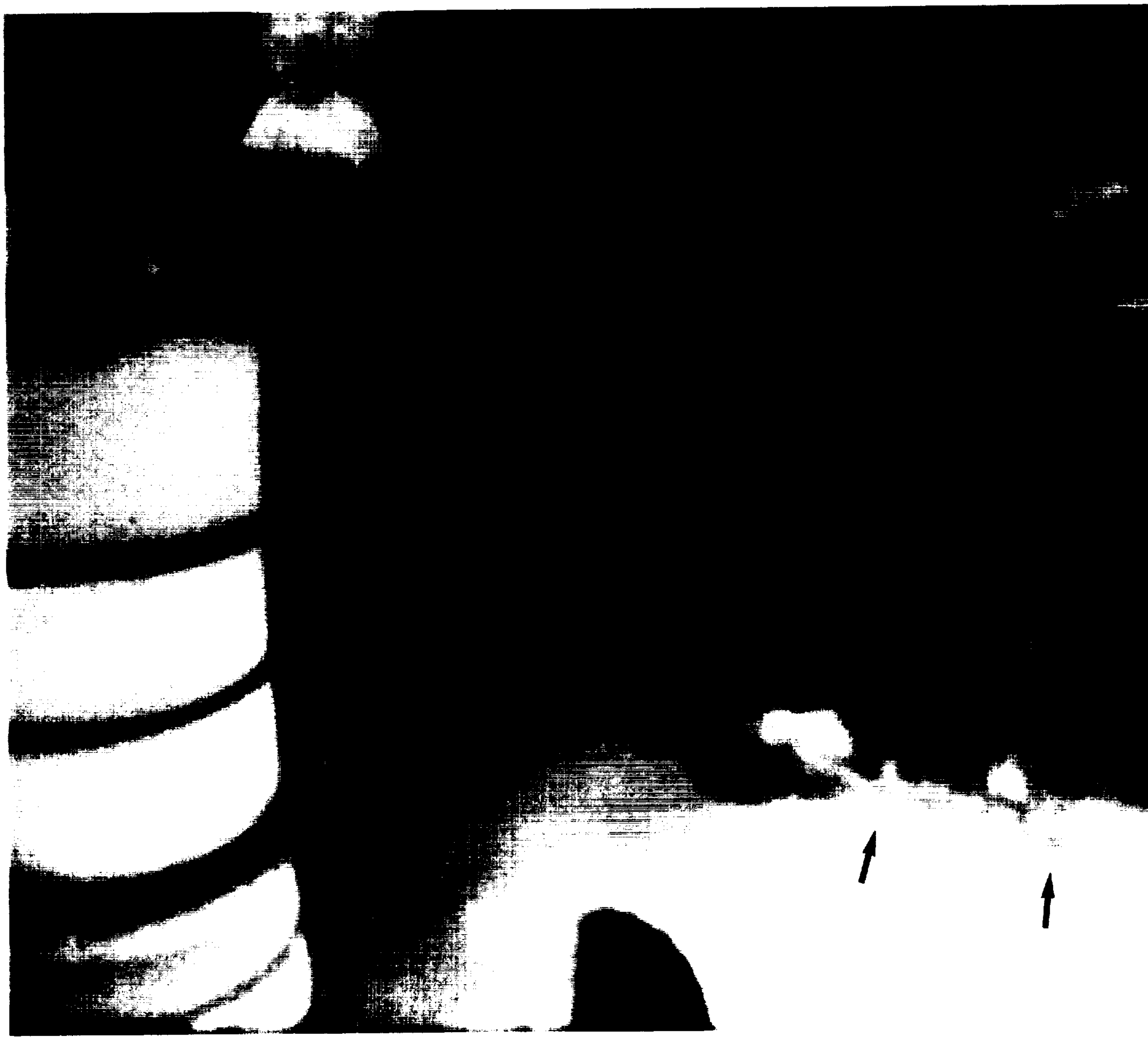


Figure 2.3.7 **Shallow Divot on ET Base TPS and White Linear Smear on Optical Plate**

A shallow divot on the ET base TPS near the left SRB attach and chipping of the LH2 electrical cable tray were noted on camera UMBL1. Also a white linear smear on the optical plate appears from left center to lower center of the FOV before SRB separation as seen on figure 2.3.7.

2.0 Summary of Significant Events Analysis

2.4 On Orbit

2.4.1 Analysis of Onboard Photography of the ET (DT0-0312)

Due to the lighting conditions and the attitude of the Orbiter, no attempt was made by the STS-49 crew to acquire photography of the external tank after separation. (See Section 6.0, Appendix D, Task #6, ET Onboard Hassleblad Photo Analysis.)

2.4.2 Electronic Still Camera

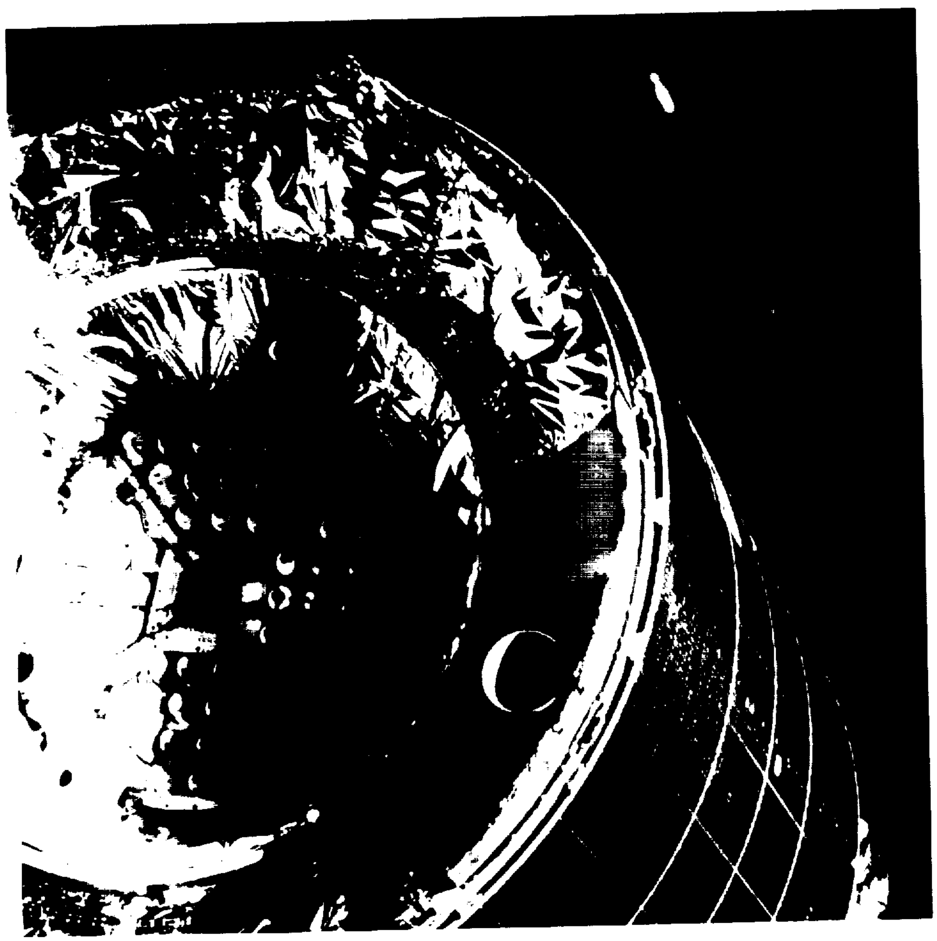


Figure 2.4.2 (A) Enhanced ESC Downlinked Image of INTELSAT

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BLACK AND WHITE PHOTOGRAPH

~~ORIGINAL PAGE COLOR PHOTOGRAPH~~

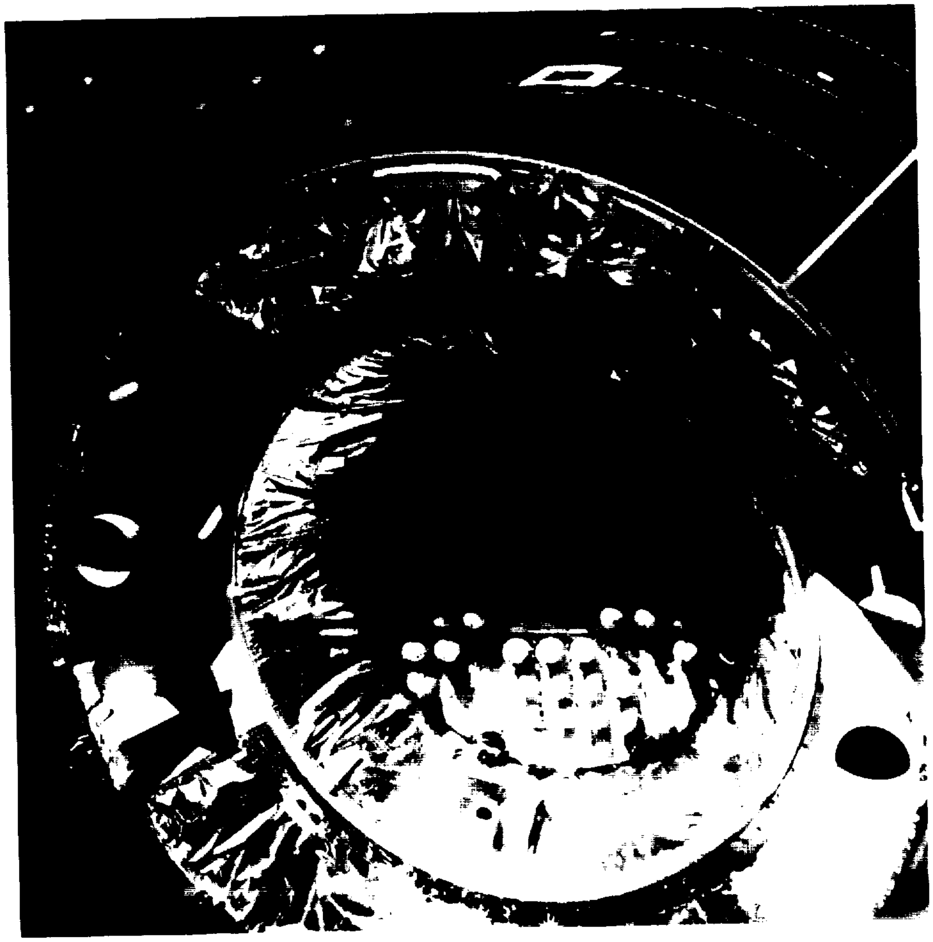

Figure 2.4.2 (B) Enhanced ESC Downlinked Image of INTELSAT

Electronic still camera (ESC) downlinked images from Endeavour of the INTELSAT prior to capture were enlarged, enhanced, and examined for sharp edges. No sharp edges that could have affected the astronauts retrieval of the satellite were noted. Figure 2.4.2 (A) is a histogram equilization of one image of INTELSAT and figure 2.4.2 (B) is an intensity mapping plus 90 degrees rotation of another ESC image. (See Section 6.0, Appendix D, Task #15, INTEL Satellite Enhancements.)

2.4.3 Assembly of Space Station by EVA Methods (ASEM) (Task #11)

The Assembly of Structures by EVA Methods (ASEM) was performed during STS-49. Due to the additional space walks required to retrieve and repair INTELSAT, ASEM procedures were substantially reduced. PTAP personnel screened these activities in real-time to gather information for future analysis and to serve as support in case of a contingency. However, less than ten percent of the crew's EVA activities were downlinked live. Two video feeds were continuously recorded on the Orbiter during the course of these activities and they will be screened at a later date to help determine positions and rates of the RMS arm, assembly structures and crew propulsion devices.

Two preliminary findings from the initial screening were: difficulty identifying the astronauts if they were more than 30 feet away from the camera (the id bands on the suits were not easily discernable) and a general problem with audio quality (with higher frequency voices become harder to understand.) Detailed notes on the initial screening can be found in Section 6.0, Appendix D, Task #11, ASEM Evaluation.

2.4.4 Orbital Debris Impact on Window W1

Figure 2.4.4 Orbital Debris Impact on Window W1

An orbital debris impact was noted by the STS49 crew on flight day 8 in the upper right hand corner of window W1 as viewed from the commander's seat. The size of the dark star burst was described as the size of a 50 cent piece. The photograph displayed in figure 2.4.4 was made during the post-landing inspection and shows a white material covering the window that is the residual fro SRB separation motors. Commander Brandenstein suggested that the dark star burst is due to the cleaning(removal) of the SRB plume residual by the debris impact. An estimate has been made that the strike occurred one inch from the edge of the window and the center of the star burst is approximately 1/16 to 1/32 of a inch in size.

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2.5 Landing Event

2.5.1 Landing Sink Rate Analysis

2.5.1.1 Landing Sink Rate Analysis Using Film

Camera E-1008 film was used to determine the sink rate of the main gear and the nose gear. The vertical stabilizer was used as a scale. Data was gathered from approximately 1 second prior to landing through touchdown. Four points on every other frame over a period of 100 frames were digitized. These points consisted of the bottom of the left main gear, a point on the runway immediately below the wheel and the top and bottom of the vertical stabilizer (as a scaling reference). The raw data was corrected for the vertical change in scale at each frame. The distance between the bottom of the wheel and the runway was computed and a linear regression was applied on this normalized vertical distance vs. time data to determine the actual sink rate. This rate was determined to be 2.0 ft/sec.

Nose gear touchdown occurred 11 seconds after main gear touchdown. Again, data was gathered for approximately 1 second just prior to nose gear touchdown. Three points on every other frame over a period of 96 frames were digitized (also from Camera E-1008). These points consisted of the top and bottom of the right nose gear wheel (as a scaling reference) and a point on the runway immediately below the wheel. The raw data was corrected for the vertical change in scale at each frame. A linear regression was performed on this normalized vertical distance vs. time data. The slope of this line was used as the sink rate of the nose gear and found to be 2.8 ft/sec. Graphs depicting the above data can be seen in Section 6.0, Appendix D, Task #3, Determine Sink Rate from Video/Film.

2.5.1.2 Landing Sink Rate Analysis Using Video

Data from TV-4 was used to determine the sink rate of the main gear and the nose gear. A vertical section of tile of known length on the right side of the Orbiter was used as a reference scale. The vertical position of the main gear was found by taking the difference between the raw vertical positions of the main landing gear and the edge of the runway with the same X coordinate over a one second period. Using the scale calculated from the known vertical reference, these differences were converted to feet. The same method was used to determine the vertical position of the nose gear. A least squares regression line was calculated from the data and the slope was used as the average sink rate. The sink rate for the main gear was determined to be 1.08 feet per second and 2.81 for the nose gear. Graphics depicting the above data may be found in Section 6.0, Appendix D, Task #3, Determine Sink Rate from Video/Film.

2.5.2 Drag Chute

2.5.2.1 Uplock Shear Pin
(Task #9)

PTAP analysts were requested to attempt to determine if the appropriate shear pin was used during installation of the drag chute into the Endeavour using the assembly video tapes. After carefully screening the tapes for scenes which displayed the shear pin, it was determined that there was insufficient information due to shadows and video resolution in the video tapes to make the determination requested. See Section 6.0, Appendix D, Task #9, Uplock Shear Pin Identification.

2.5.2.2 Drag Chute Performance
(Task #10)

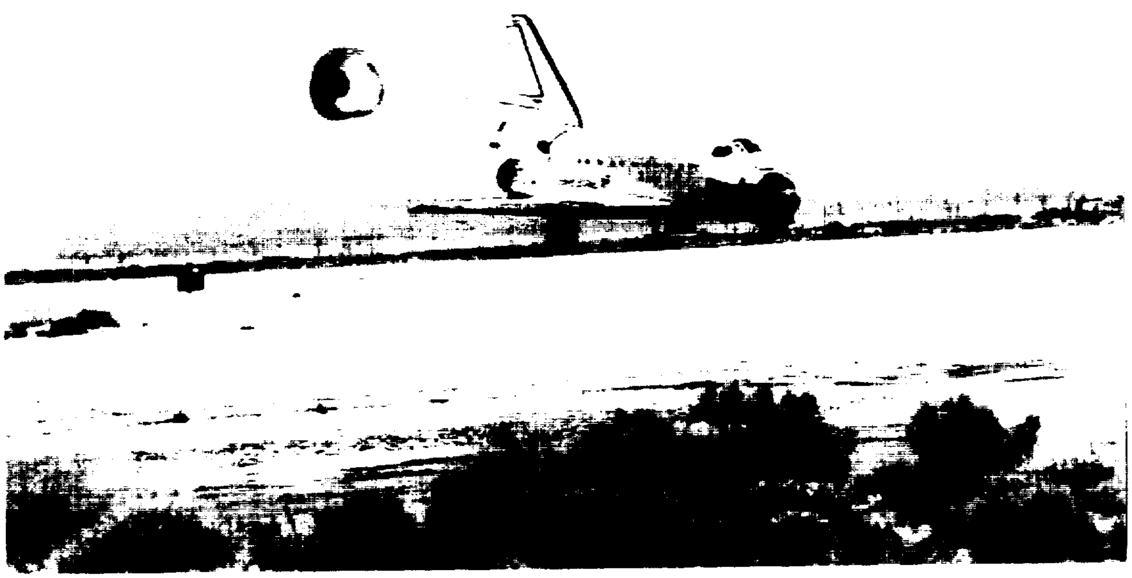


Figure 2.5.2.2 Chute Inflated in Reefed Configuration

Figure 2.5.2.2 depicts just one of many stages of the drag chute deployment. The various stages are drag chute initiation, pilot chute inflation, bag release, chute inflation in reefed configuration, disreefing initiation, full chute inflation and chute release. The analysis of the drag chute deployment and its effect upon the vehicle is still being performed as of the writing of this report and a separate report will be generated describing the results of this analysis upon completion. See Section 6.0, Appendix D, Task #10, Drag Chute Performance Analysis.

2.5.3 Post-Landing Inspection of Damage to the Orbiter

Although the launch and landing films indicated that STS-49 was an unusually clean mission, eleven hits greater than one inch were found by KSC on the Orbiter during the post-landing inspection. Several of these hits included TPS damage on the right side of the Orbiter nose and the

base heat shield. A small segment of the aft port payload bay door seal appeared misaligned. Streaks were noted on the TPS forward of the hydrogen umbilical.

2.5.4 Post-Landing Inspection of Debris Found on Runway

A half inch screw and a small green cylindrical object were seen on the ground during the post-landing inspection.

2.6 Other Normal Events

Other normal events observed included: normal pad debris; SRB flame duct debris; RCS paper debris; white debris (probably ice) from the ET/Orbiter, TSM umbilical areas and the GUCP disconnect during liftoff; left inboard elevon motion was noted during liftoff; ET aft dome out-gassing and charring; vapor off SRB stiffener rings; condensation vapor trails off both wings after tower clear; white flashes in the SSME plume throughout the roll maneuver; indication of wind shear in the SRB plume; atmospheric bow waves; SRB exhaust plume brightening at tail off; and slag noted after SRB separation. No further analysis has been requested for any of these events.

Appendix B. MSFC Photographic Analysis Summary

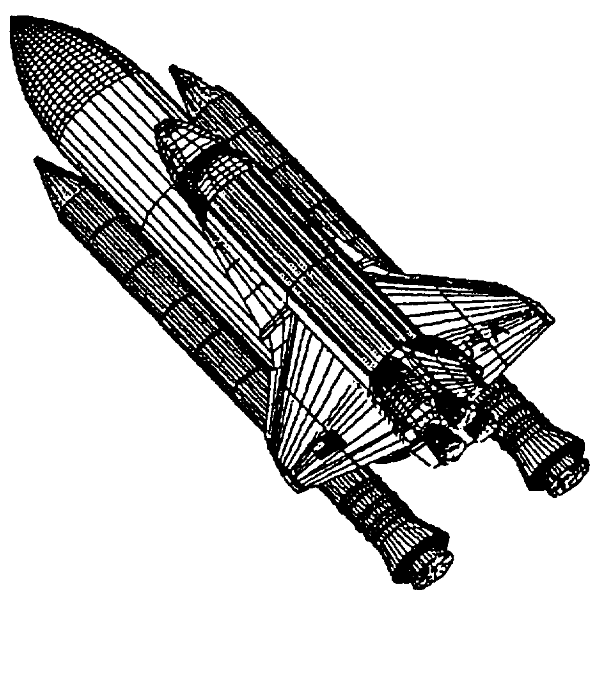
NASA
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-49



MSFC - Form 454 (Rev. October 1976)

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-49

FINAL

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STS-49 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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APPENDIX B - INDIVIDUAL FILM CAMERA ASSESSMENT *

APPENDIX C - INDIVIDUAL VIDEO CAMERA ASSESSMENT *

* Photographs in the individual camera assessments are representative photographs and are not necessarily photographs taken from this particular launch.

June 8, 1992

I. INTRODUCTION

Space Shuttle Mission STS-49, the first flight of the Orbiter Endeavour, was conducted May 7, 1992 at approximately 6:40 P.M. Central Daylight Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-49 included, but were not limited to the following.

a. Overall facility and Shuttle vehicle coverage for anomaly detection
b. Verification of cameras, lighting and timing systems
c. Determination of SRB PIC firing time and SRB separation time
d. Verification of Thermal Protection System (TPS) integrity
e. Correct operation of the following:
    1. Holddown post blast covers
    2. SSME ignition
    3. LH2 and LO2 17" disconnects
    4. GH2 umbilical
    5. TSM carrier plate umbilicals
    6. Free hydrogen ignitors
    7. Vehicle clearances
    8. GH2 vent line retraction and latch back
    9. Vehicle motion

There was one special test objectives for this mission.

a. SRB holddown post shoe rotation quantification

III. CAMERA COVERAGE ASSESSMENT:

Film was received from sixty of sixty-three requested cameras as well as video from twenty-three of twenty-three requested cameras. The following table illustrates the camera data received at MSFC for STS-49.

CAMERA DATA RECEIVED FOR STS-49

	16mm	35mm	Video
MLP	28	0	3
FSS	7	0	3
Perimeter	3	5	6
Tracking	0	16	11
Onboard	1	0	0
Totals	39	21	23

A detailed individual motion picture camera assessment is provided as Appendix B. Appendix C contains detailed assessments of the video products received at MSFC.

a. Ground Camera Coverage:

Photographic coverage of STS-49 ranged from good to poor. Most cameras on this mission experienced dark exposures due to a forty minute hold during the evening twilight. Coverage from the trackers was limited due to cloud coverage. Camera E-12 experienced a timing problem. The timing resets to zero and continues to stay there throughout liftoff. Camera E-54 experienced some camera jitter, and on camera E-211, processing scratches were noted. The shoe targets on post M-1 and M-5 were not totally visible from camera EX-1 and EX-4, respectively.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras experienced some problems. For camera E-301 onboard the right SRB, the film was not exposed. For camera E-302 onboard the left SRB, the film broke at the start of rewinding. One 16mm camera and one 35mm were flown to record SRB and ET separations. The 16mm provided coverage of the left SRB separation only. All other onboard film was under-exposed due to low light levels and provided no data.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included: pad debris rising and falling as the vehicle lifts off; debris induced streaks in the SSME plume; and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detectors, purge barrier material and SRB thermal curtain tape.

b. Plume Flares in Video Signal:

Apparent orange flashes were noted in the SSME plumes during ascent as seen from video camera TV-5 at 128:23:42:58.697 UTC, (figure one). These flashes were not evident on the film or any other video camera. Camera TV-5 is a tube type video camera which is subject to blurring images when the camera is moved. The flashes are a blurring of the SSME plume.

c. Base Heat Shield Motion:

During SSME start transient, the base heat shield exhibited an axial movement at the center of the engine cluster. The movement was intermittent and oscillatory. The motion ceased after the SSMEs reached mainstage. A historical review was conducted to determine if similar motion was evident on other orbiters. Axial base heat shield motion was observed on all of the other orbiters. A summary of the research findings is presented in Table IV.1.

BASE HEAT SHIELD MOVEMENT COMPARISON
TABLE IV.1

ORBITER	MISSION	CAMERA	COMMENTS
Columbia	STS-1	E-19	No flexing of the base heat shield was noted - good view of heat shield
Columbia	STS-30	E-19	Flexing of the base heat shield was observed
Columbia	STS-32	E-19	Flexing of the base heat shield was observed
Columbia	STS-40	E-19	No flexing of the base heat shield was noted - good view of heat shield
		E-20	Inconclusive due to camera vibration
Challenger	STS-6 FRF	E-20	Flexing of the base heat shield was observed
Challenger	STS-6	E-19	Flexing of the base heat shield was observed - good view of heat shield

Challenger	STS-11	E-19	Flexing of the base heat shield was observed
Discovery	STS-14	E-19	Motion noted in eyelid blanket only - good view of heat shield
Discovery	STS-26 FRF	E-19	Flexing of the base heat shield was observed - good view of heat shield
Discovery	STS-48	E-19	No flexing of the base heat shield was noted - good view of heat shield
Atlantis	STS-28	E-19	Flexing of the base heat shield was observed - good view of heat shield
Atlantis	STS-44	E-19	No flexing of the base heat shield was noted - good view of heat shield
Atlantis	STS-51J FRF	E-19	Inconclusive due to camera vibration
Endeavour	STS-49 FRF	E-19	Flexing of the base heat shield was observed
Endeavour	STS-49 FRF	E-20	Flexing of the base heat shield was observed

A motion analysis of the base heat shield motion was conducted in order to possibly determine frequency and amplitude. Figure two shows the area that was measured using cameras E-19 and E-76. The X_0 and Y_0 (Orbiter axis X and Y) data are shown in figures three and four. The data from camera E-19 were taken using a reference point on the TSM to measure displacement. Camera E-76 data were a result of displacement relative to the camera optics.

Due to the digitization noise created by the large scale factors, a frequency could not be calculated. However, during the oscillation, the base heat shield deflected approximately 1.0 inch in the $-X_0$ direction.

The following chart provides the RMS data accuracy using data points taken prior to visible motion of each camera.

CAMERA	HORIZONTAL	VERTICAL
E-19	+0.150	+0.134
	-0.135	-0.162
E-76	+0.216	+0.167
	-0.188	-0.150

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times were determined from cameras which view the SRB holddown posts numbers M-1 and M-2. These cameras record the explosive bolt combustion products.

POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	128:23:40:00.028
M-2	E-8	128:23:40:00.027

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 31.9 inches. Figure five is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. These data were derived from camera E-79.

c. SRB Separation Time:

SRB separation time for STS-49 was determined to be 128:23:42:07.25 UTC taken from camera E-212.

d. SRB Holddown Post Shoe Rotation Study:

A study was performed on this mission to determine the aft skirt/shoe rotation effects at T-Zero due to the radial biasing of the MLP holddown post to 0.060 inches.

Cameras EX1, EX4, E-27 and E-28 were used to provide close-in coverage of the shoes and holddown posts M-1, M-5, M-3 and M-7, respectively. However, due to improper camera orientation, rotation data could not be gathered for holddown posts M-5 and M-7.

Figure six shows the locations of the cameras and holddown posts and direction of "horizontal motion" relative to the attached plots.

Figures seven and eight show the target positions of the motion data taken relative to a stationary target on the MLP. Figure seven represents post M-1. Figure eight represents post M-3.

The following table provides the RMS data accuracy for each post measured in inches.

Post	Horizontal	Vertical
M-1	+.015	+.013
	-.018	-.015
M-3	+.018	+.018
	-.018	-.021

The motion data are presented in figures nine through fourteen. These data have been filtered to remove the noise from the interactive digitization process.

Figure 1

Apparent Orange Flashes from Video Camera TV-5

Figure 2

Area Measured to Determine Base Heat Shield Motion

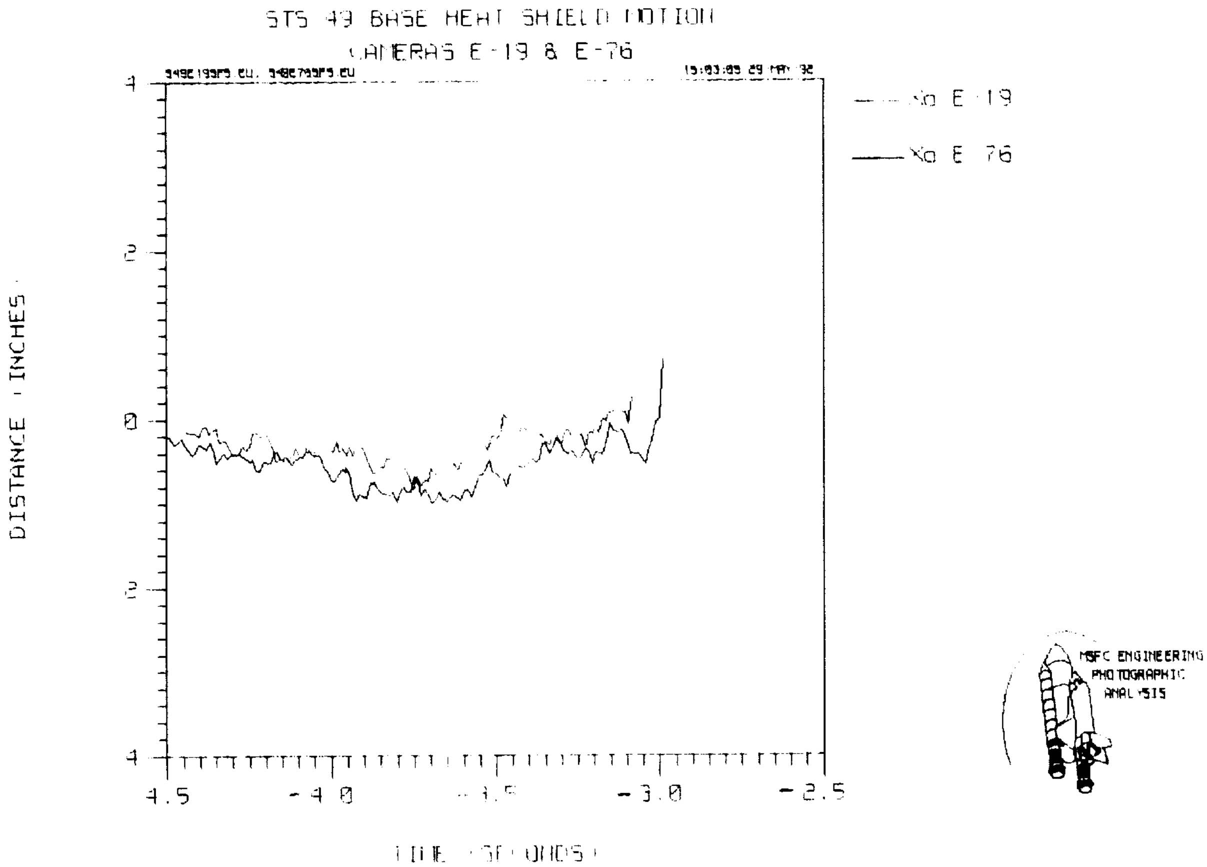

Figure 3

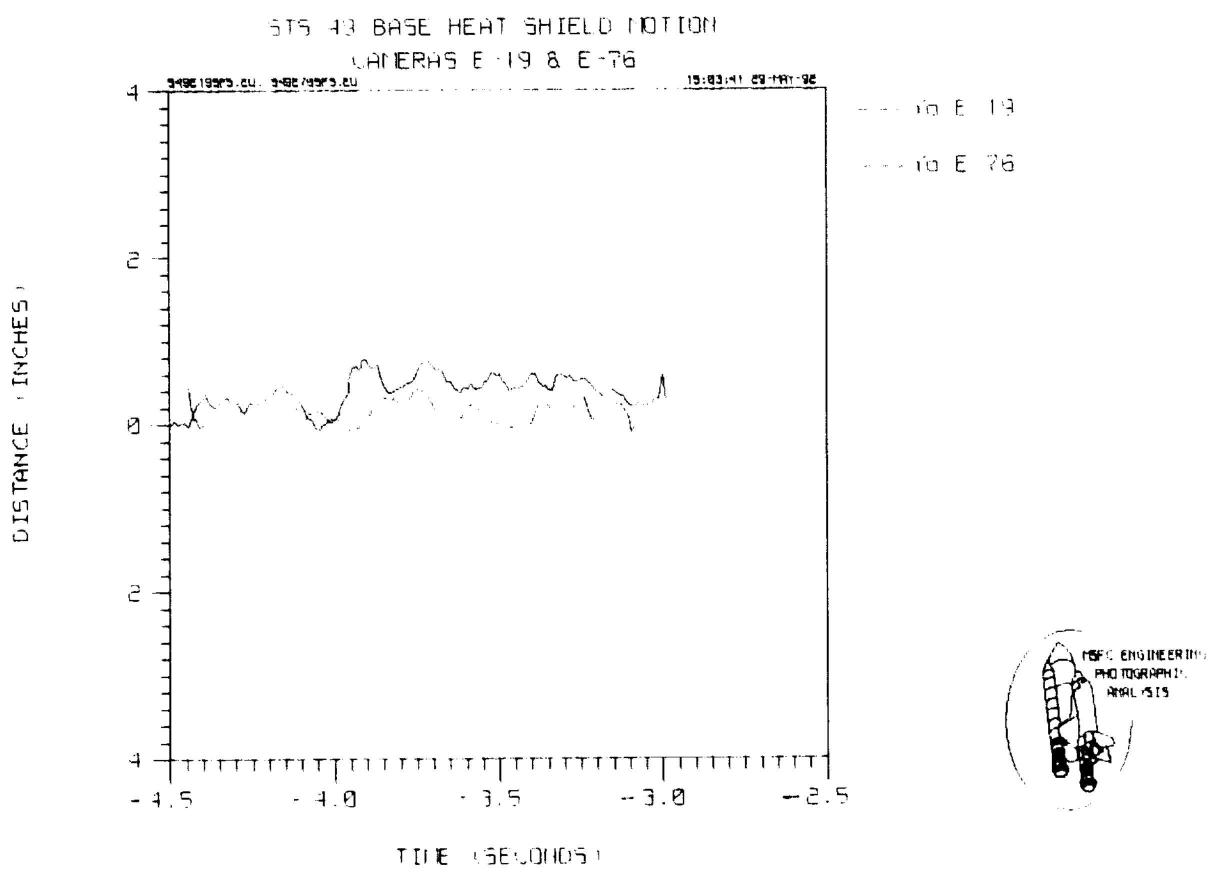

Figure 4

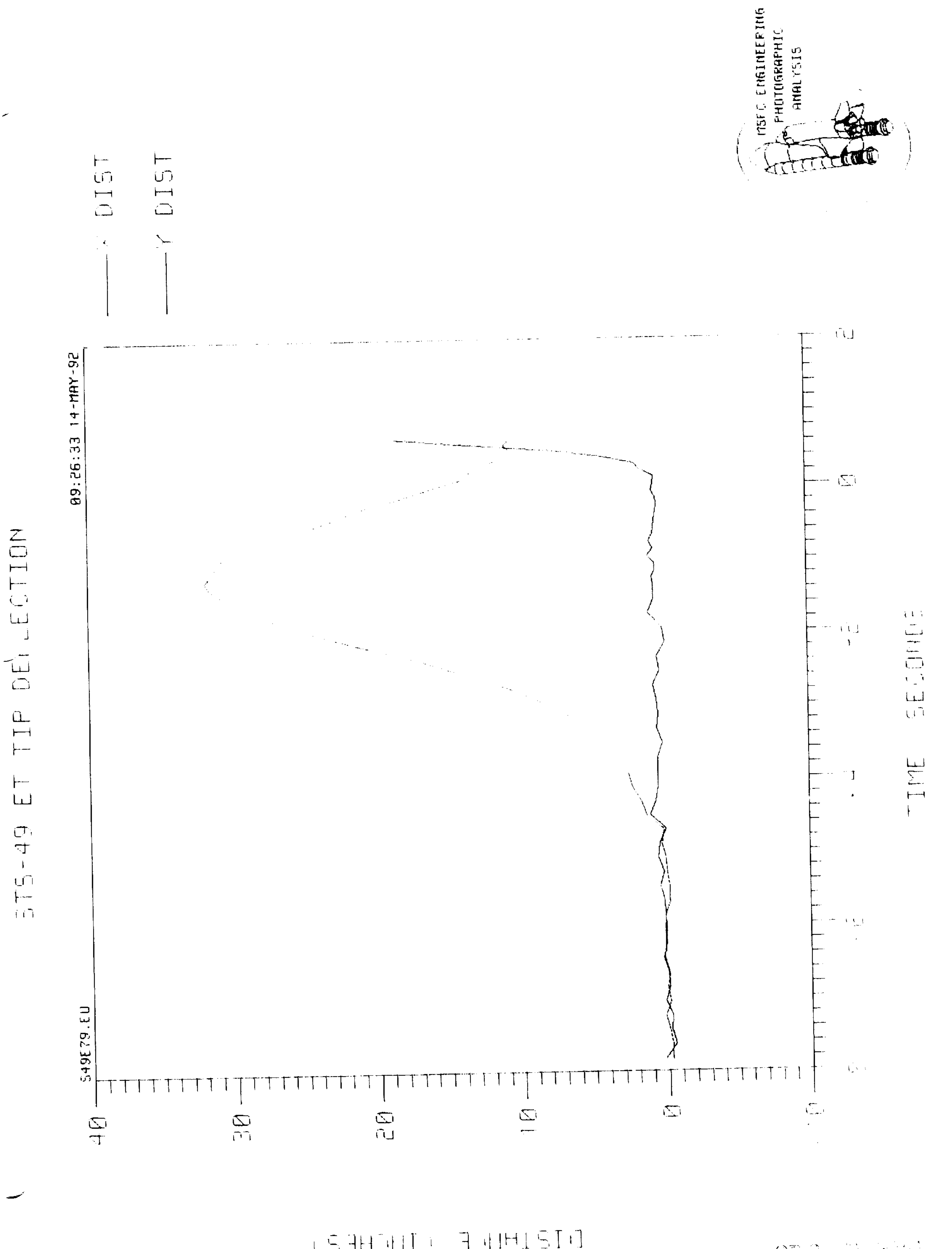
STS-49 ET TIP DEFLECTION
09:26:33 14-MAY-92
S49E79.EU
X DIST
Y DIST
MSFC ENGINEERING PHOTOGRAPHIC ANALYSIS
TIME SECONDS
DISTANCE (INCHES)
40
30
20
10
0
-10

Figure 5

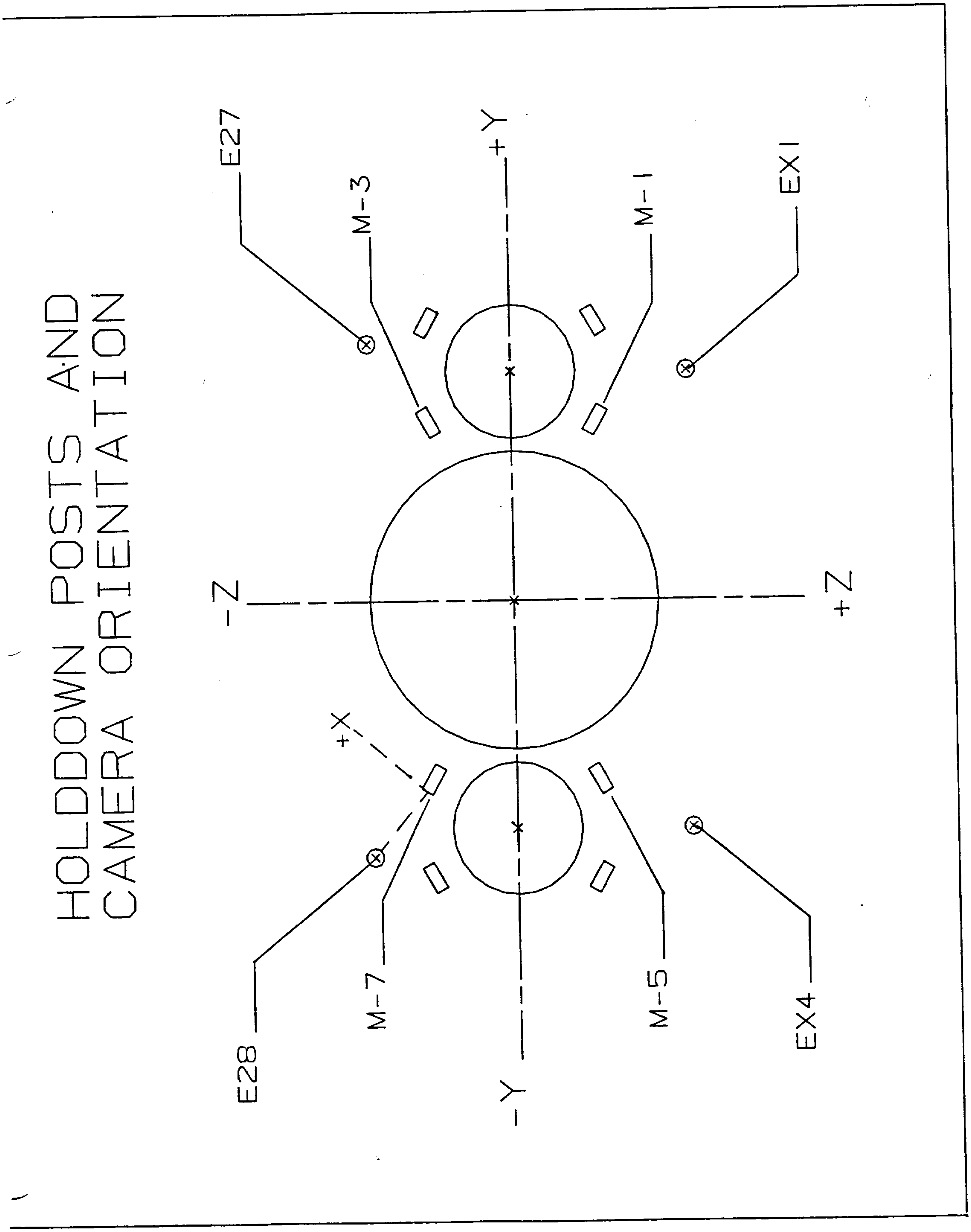

Figure 6

Camera Locations

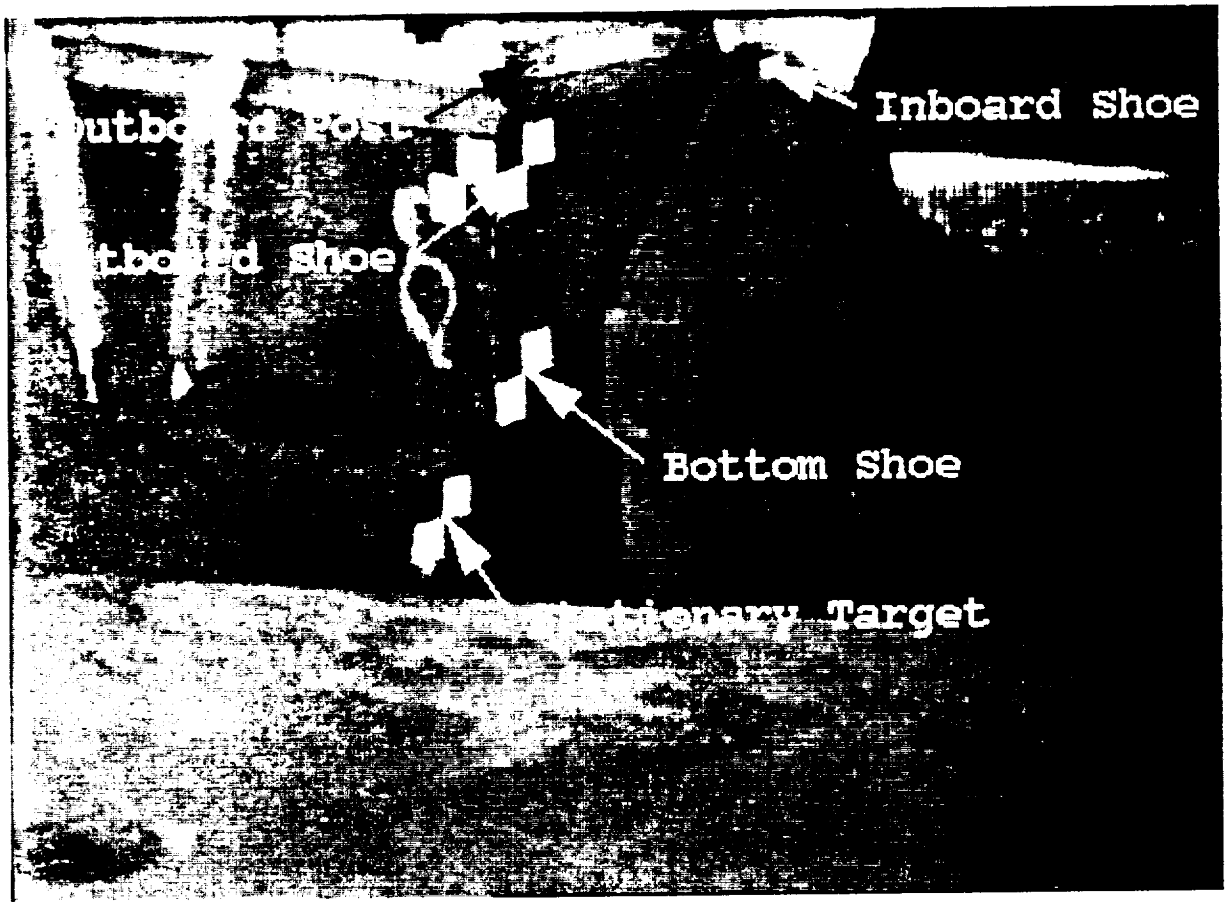

Figure 7

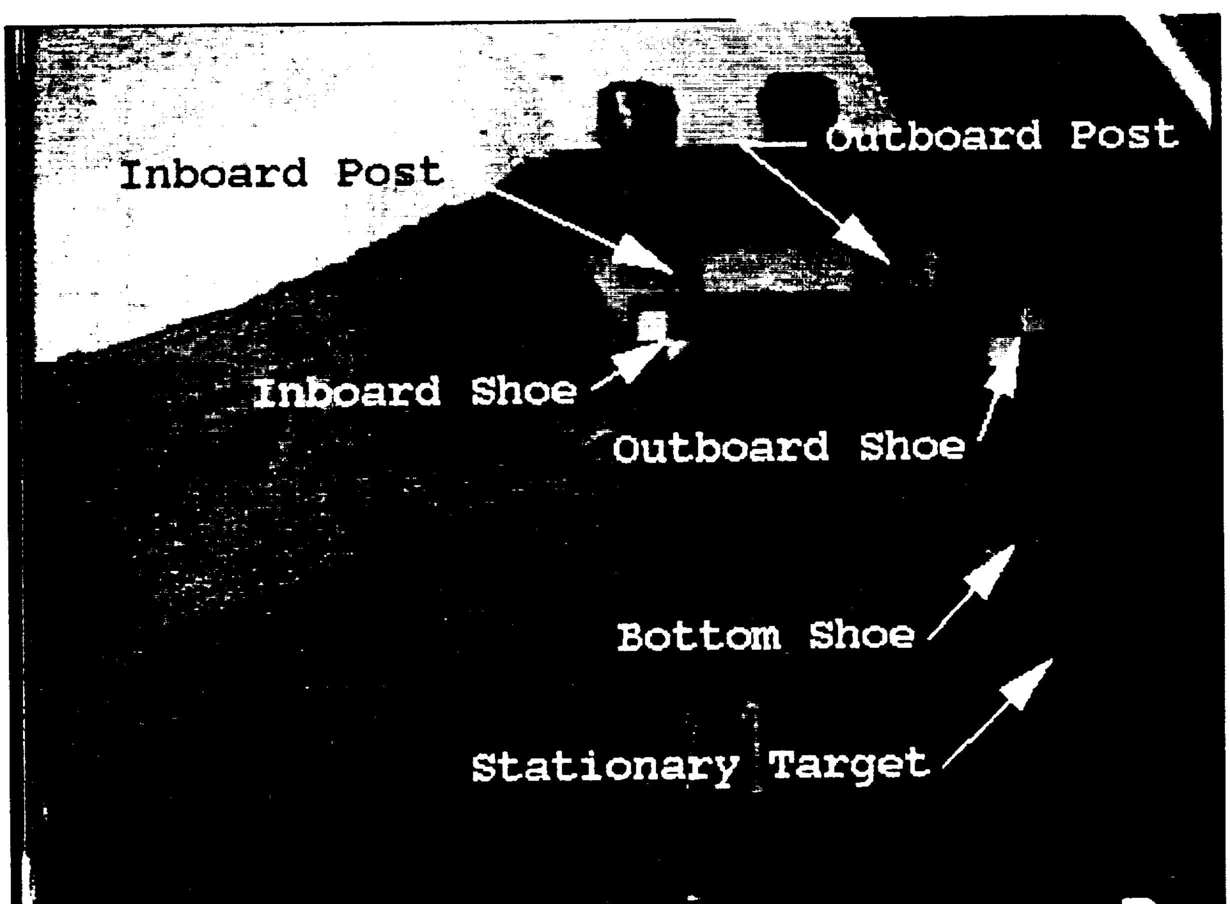

Figure 8

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COLOR PHOTOGRAPH

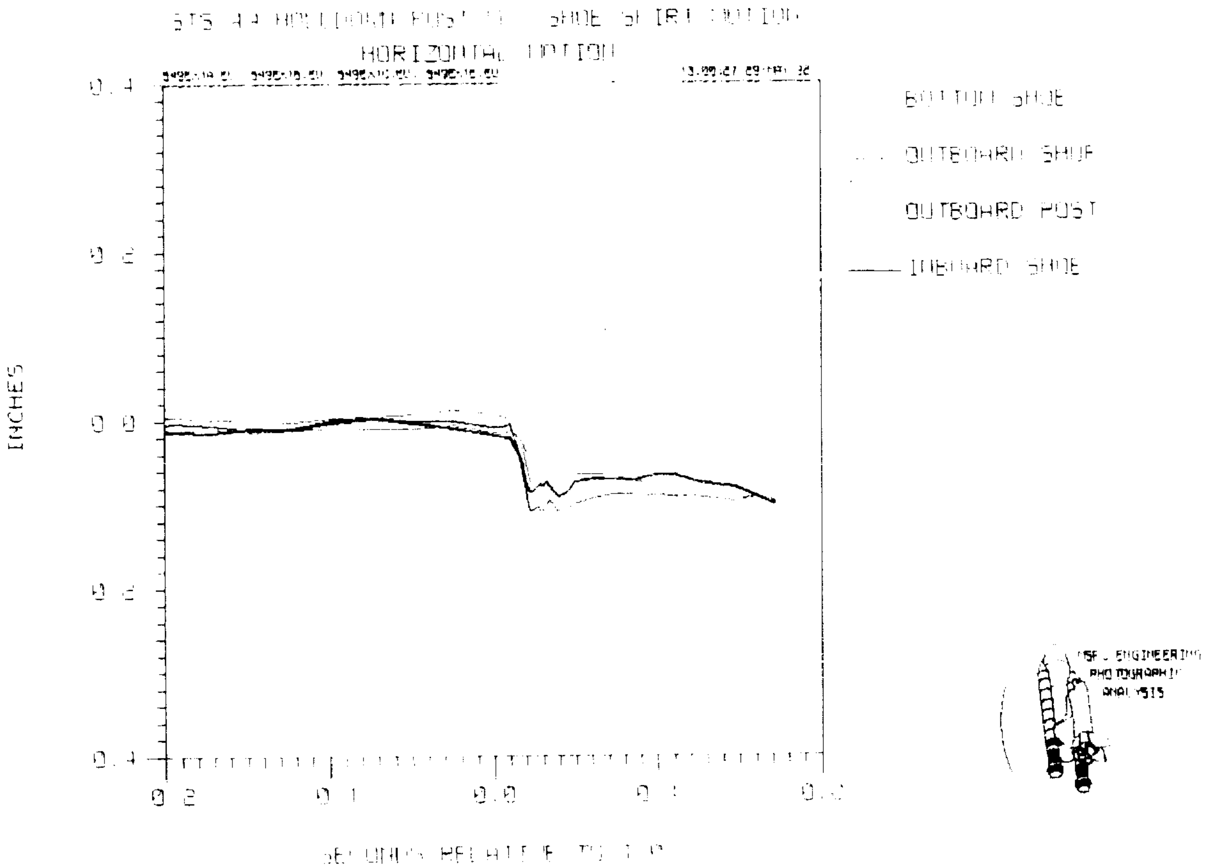

Figure 9

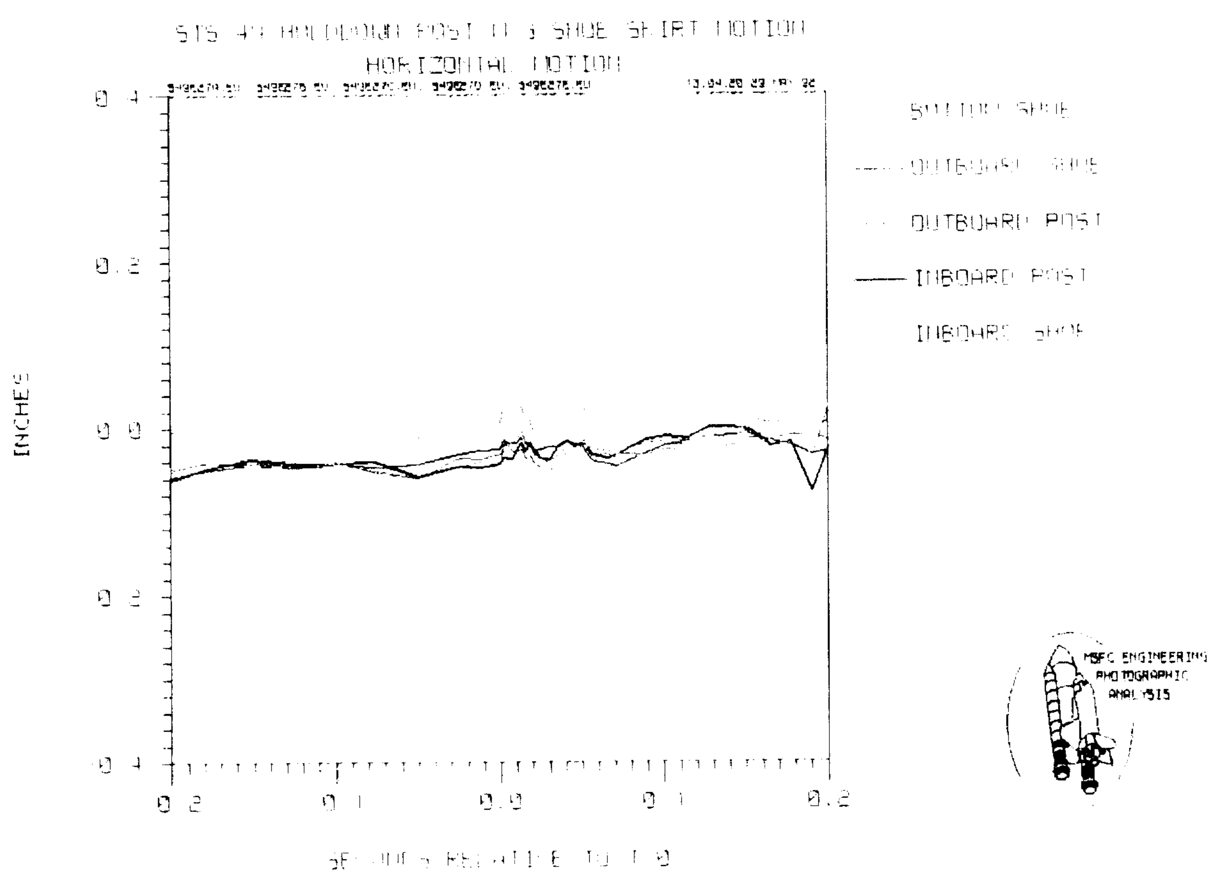

Figure 10

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COLOR PHOTOGRAPH

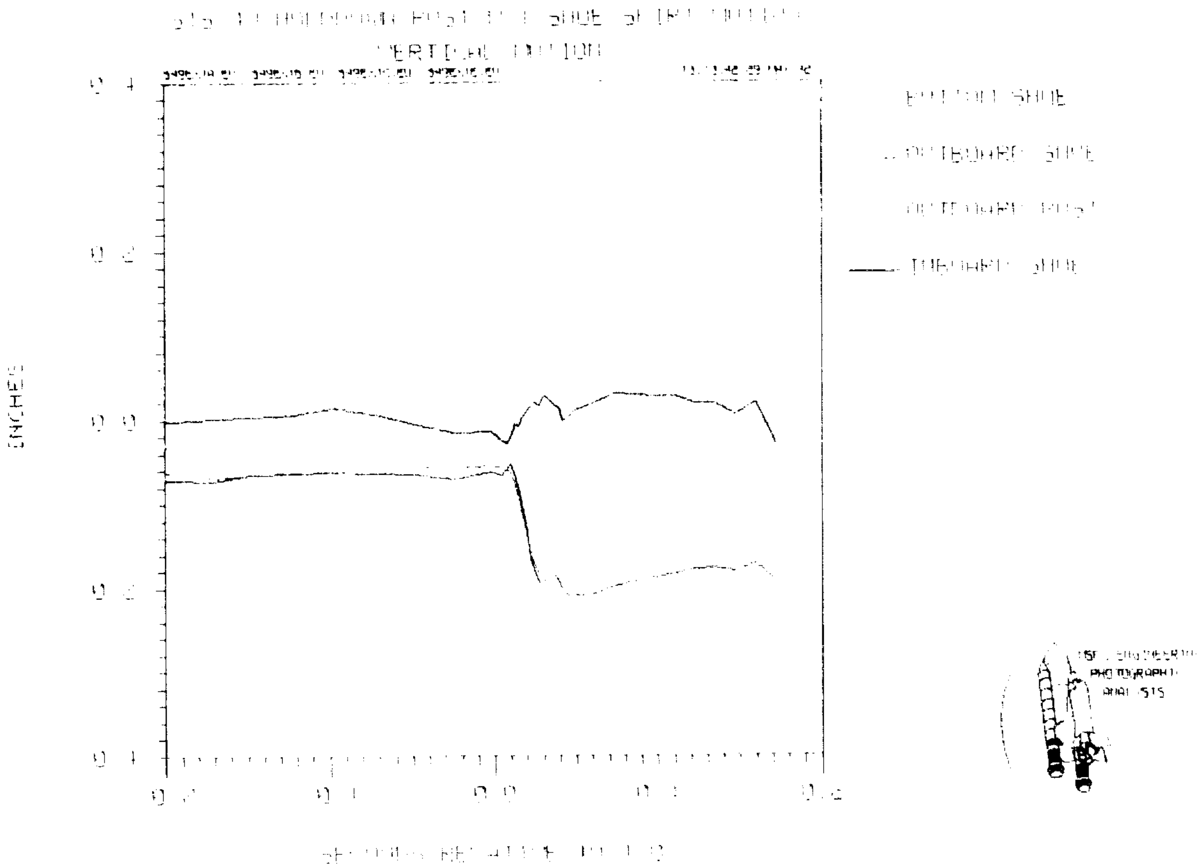

Figure 11

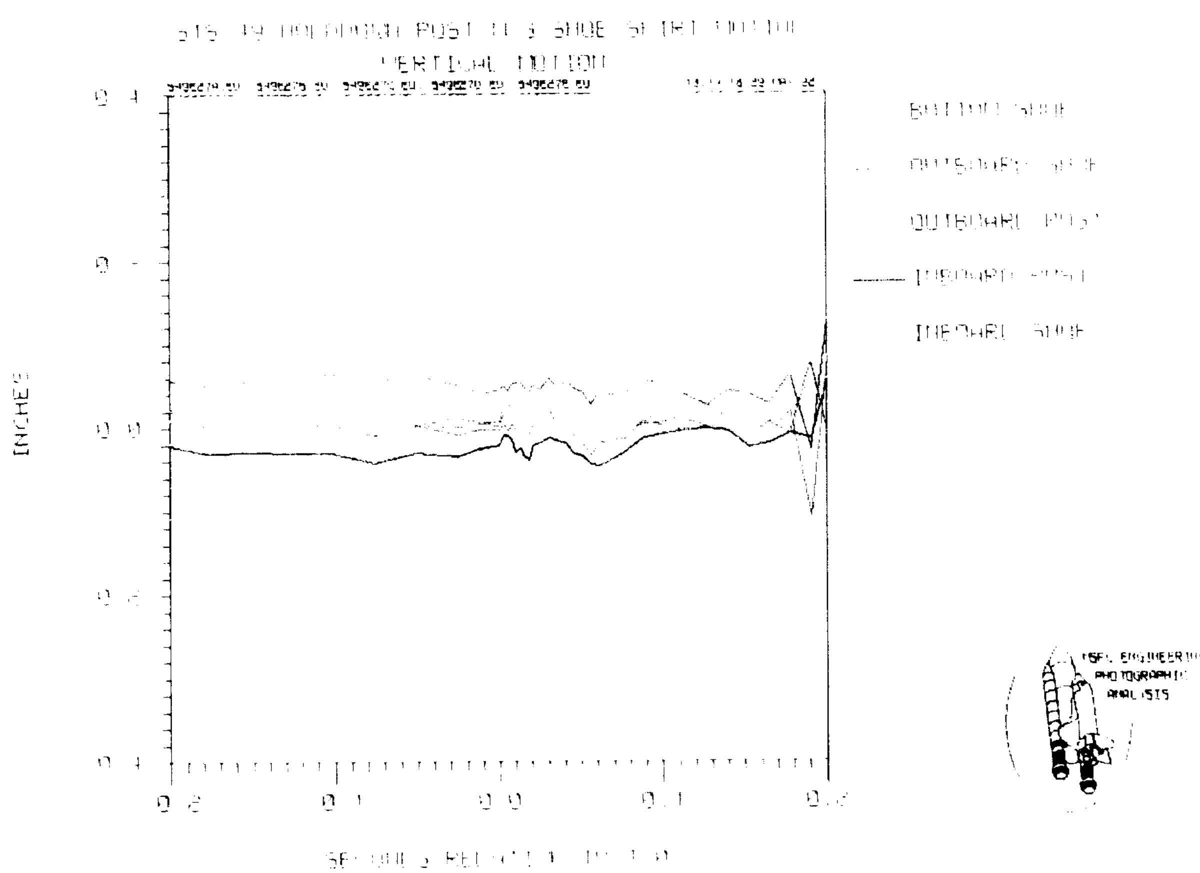

Figure 12

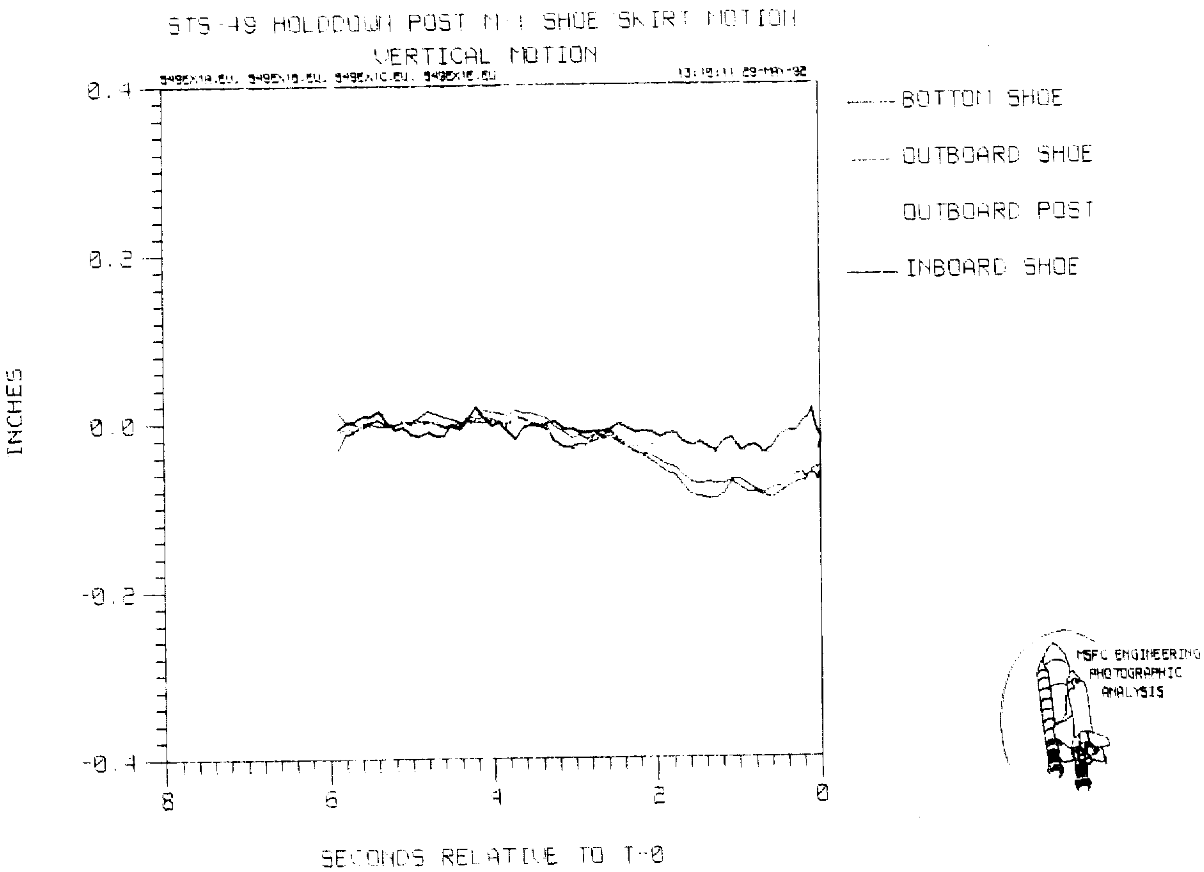

Figure 13

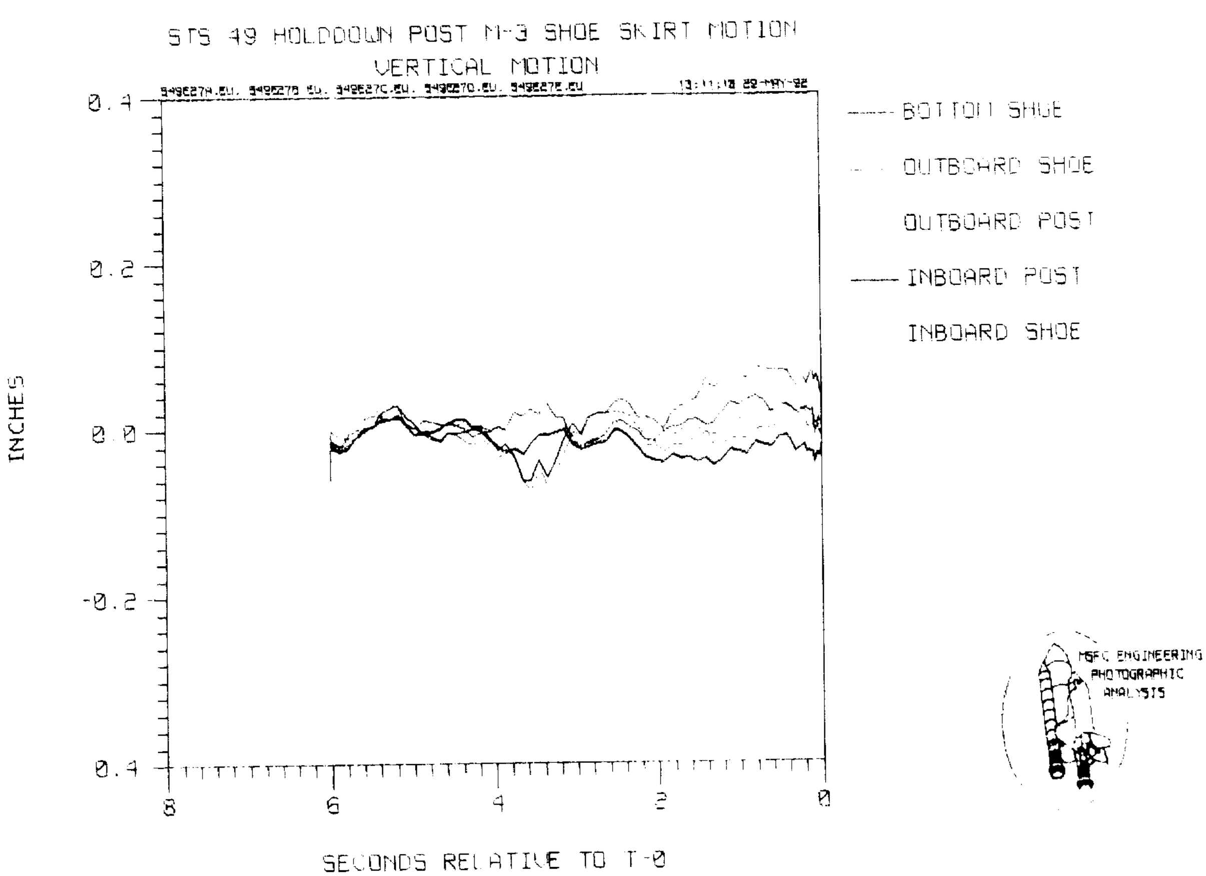

Figure 14

ORIGINAL PAGE
COLOR PHOTOGRAPH

Appendix C. Rockwell Photographic Analysis Summary

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Rockwell International

June 16, 1992

In Reply Refer to 92MA2832

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Attention: L. G. Williams (WA)

Contract NAS9-18500, System Integration, Transmittal of the Rockwell Engineering Photographic Analysis Report for the STS-49 Mission.

The System Integration Contractor hereby submits the Engineering Photographic Analysis Summary Report in accordance with the Space Shuttle Program Launch and Landing Photographic Engineering Evaluation Document (NSTS 08244).

Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39B Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-49 launch conducted on May 7, 1992, at approximately 4:40 pm (PDT) from the Kennedy Space Center (KSC) and for the landing on May 16, 1992 at Edwards Airforce Base (1:58 pm PDT)

Rockwell received launch films from 85 cameras (62 cine, 23 video) and landing films from 15 cameras (7 cine, 8 video) to support the STS-49 photographic evaluation effort.

All ground camera coverage for this mission including coverage on the MLP, FSS and tracking cameras were good. However, due to the accumulation of clouds, many of the tracking video and films reviewed were obstructed after the vehicle went through the cloud cover. This hampered analysis and possible detection of debris and/or anomalies.

Overall, the films showed STS-49 to be a clean flight. Several pieces of ice from the ET/ORB umbilicals were shaken loose at SSME ignition, but no damage to the Orbiter Thermal Protection System (TPS) was apparent. The usual condensation and water vapors were seen at the ET aft dome and the SRB stiffener rings and dissipated after the completion of the roll maneuver. No vapor was observed in the vicinity of the rudder/speed brake at liftoff. Charring of the ET aft dome and recirculation were visible and normal. Booster Separation Motor (BSM) firing and SRB separation also appeared to be normal.

(Packing Sheet No. DM92-15279)

Nominal performance was seen for the MLP and FSS hardware. FSS deluge water was activated prior to SSME ignition and the MLP rainbirds were activated at approximately 1 second Missions Elapsed Time (MET), as is normal. There were no SRB holddown support post bolt hang-ups, and all blast deflection shields closed prior to direct SRB exhaust plume impingement. Both TSM umbilicals released and retracted as designed. The ET GH2 vent line carrier dropped normally and latched securely with no rebound. No anomalies were identified with the ET/ORB LH_2 umbilical hydrogen dispersal system hardware.

STS-49 was the seventh flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). The link is designed to increase the plunger velocity and seating accuracy, while leaving the holddown bolt ejection velocity unchanged. This prevents frangible nut fragments and/or NSI cartridges from falling from the DCS, while not increasing the probability of a holddown bolt hang-up.

One major or significant event was identified by the film review team at KSC. During the film review the team observed an apparent movement of the Orbiter base heat shield between the SSME's during SSME start-up. This movement appeared to subside as the SSME plumes stabilized. This event and other events noted by the Rockwell film/video users during the review and analysis of the STS-49 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

<u>COMMENTS</u>

1. Flexing (an up and down motion) was noted in the base heat shield in the centerline area between the SSME cluster from cameras E19, E20, E76, and E77. The flexing occurred at approximately T-4.5 seconds and ended after all SSME's had started up at about T-3.0 seconds MET. In order to determine if the base heat shield flexing seen on STS-49 was unique to OV-105, films from previous flights and Flight Readiness Firing (FRF) tests were screened. Base heat shield movement was observed on STS-1 (OV-102), STS-6, STS-51F (OV-099), STS-41D, STS-48, STS-42 (OV-103) and STS-51J, STS-44, STS-45 (OV-104). In addition, motion was observed on STS-11, STS-32, STS-35, STS-40 by MSFC and STS-14, STS-28 by KSC.

   Since flexing by the base heat shield has been seen on previous missions it is not unique to OV-105 and may be a normal occurrence. A hypothesis is that the motion is caused by pressure waves from the main engines during ignition.

   An analysis has been conducted by JSC and MSFC to measure the displacement and frequency of the base heat shield up and down motion. Details of the base heat shield flexing study are available in the JSC and MSFC reports. No additional action(s) are currently planned.

2. On cameras OTV-170, E-1, E-2, E-3, E-, E-16, E-18, E-19, E-20, E-23, E-24, E-30, E-36, E-62, E-76, E-77 and E-222 an orange vapor (possibly free burning hydrogen was noted rising toward the vertical stabilizer just prior to SSME ignition. This vapor has been noted on previous missions. It is not considered an issue and no follow-up action is planned.

3. Several white flashes were seen in the SSME #1, #2, and #3 plumes after SSME ignition on cameras E-3, E-5, E-52, E-57, and E-76. These have been seen on previous missions and no follow-up action is planned.

4. On cameras E-52, E-54, and E-79 a tumbling piece of debris (light/dark) was seen near the underside of the Orbiter at mid-fuselage falling aft during liftoff. Review by JSC, KSC and Rockwell concluded that it was a piece of ice from the LO2 feedline. No follow-up action is required.

5. On cameras E-5, E-6, and E-25 a white piece of rectangular debris was seen falling from above the LO2 ET/ORB umbilical and past the right inboard elevon at liftoff. This debris is probably ice from the LO2 feedline on the ET and is not considered an issue.

6. Several orange flares were noted in the SSME plumes after the roll maneuver and prior to the SRB plume brightening. These observations have been seen on previous missions and are understood to be burning of propellant impurities. This event was noted on cameras TV-5, ET-212, E-204, E-205, E-208, E-212, E-218, and E-220 and is not considered an issue.

7.. Several typical events reported on other launches were observed on STS-49. These events are not a concern, but are documented here for information only:
   - Ice debris falling from the ET/Orbiter Umbilical disconnect area.
   - Debris (Pad, insta-foam, Water trough) in the holddown post areas and MLP
   - Butcher paper falling from the RCS
   - Recirculation or expansion of burning gases at the aft end of the SLV
   - Slight TPS erosion on the base heat shield during SSME start-up.
   - Throat plug material which was ejected from the SRB flame duct north of the vehicle at liftoff;
   - Body flap motion during the maximum dynamic pressure (Max-Q) region which appeared to have an amplitude and frequency similar to those of previous missions.
   - Condensation vapor trails off both wings after the vehicle cleared the tower.
   - Charring of ET aft dome.
   - SRB plume brightening, prior to SRB separation.
   - Linear optical distortions, possibly caused by shock waves or ambient meteorolgical conditions near the vehicle, after the roll maneuver.
   - Holddown post shoe rotation during liftoff which was observed to be similar to that seen on previous missions.

8. Cameras E33 and E41 - OMRSD File IX Vol. 5, Requirement No. DV08P.010 requires an analysis of launch pad film data to verify that the initial ascent clearance separation between the left SRB outer mold line and the falling ET vent umbilical structure does not violate the acceptable margin of safety.

A qualitative assessment has been conducted and positive clearances between the left SRB and the ET vent umbilical have been verified. The films showed nominal launch pad hardware performance, and no anomalies were observed for the SRB body trajectory.

9. Cameras E7-16 and E27-28 - OMRSD File IX Vol. 5, Requirement No. DV08P.20 requires an analysis of film data of SRM nozzle during liftoff to verify nozzle to holddown post drift clearance.

   A qualitative assessment of the launch films has been completed. No anomalies were observed for the SRM nozzle trajectory and positive clearances between the SRB nozzles and the holddown posts were verified.

10. The landing of STS-49 occurred on runway 22 at Edwards Airforce Base. Good video and film coverage of the first use of the new drag chute deploy was obtained. The drag parachute system performed as expected. All sequenced events occurred as planned and no hardware anomalies were observed.

    Analysis continues in the areas of compartment door trajectory, reefed main chute operation, and riser position relative to the Orbiter stinger. The results of this analysis will be used to validate models against actual flight data, and to allow accurate predictions for future flights.

This letter is of particular interest to Mr. W. J. Gaylor (VF2) and Mr. R. W. Hautamaki (WE3) at JSC. The Integration Contractor contacts are R. Ramon at (310) 922-3679 or C. I. Miyashiro at (310) 922-0214.

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15. Supplementary Notes

16. Abstract

A Debris/Ice/TPS assessment and integrated photographic analysis was conducted for Shuttle Mission STS-49. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and integrated photographic analysis of Shuttle Mission STS-49, and the resulting effect on the Space Shuttle Program.

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